THE QUANTIFICATION OF SOIL NUTRIENT REGIME IN BRITISH FORESTS AND ITS ASSESSMENT FROM GROUND VEGETATION AND HUMUS TYPE

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Title of Thesis **THE QUANTIFICATION OF SOIL NUTRIENT REGIME IN BRITISH FORESTS AND ITS FIELD ASSESSMENT FROM GROUND VEGETATION AND HUMUS TYPE**

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The nutrient regime of forest soils is one of the major abiotic influences on forest stand development. Its assessment is therefore essential to ecologically appropriate silviculture. This is reflected in the new system of "Ecological Site Classification" being developed by the Forestry Commission. Soil nutrient regime will be one of three main descriptors of site quality, alongside climate and soil moisture regime.

A programme of simultaneous sampling for soil chemistry, humus type and ground vegetation species composition was carried out at 70 forest sites throughout mainland Great Britain. The intention was to derive a quantified definition of soil nutrient regime and to demonstrate that both ground vegetation species composition and humus type could aid its assessment in the field.

Soil samples were subjected to laboratory analysis to measure the following nutrient parameters:- pH, loss-on-ignition, moisture content, total phosphorus and the availability of nitrogen, phosphorus, calcium, magnesium and potassium. Nitrogen was determined in the form of mineral components both before and after an aerobic incubation. Vegetation descriptions were treated by the assignment of indicator values to each species and the calculation of an abundance weighted site mean indicator value. Initially the R and N values proposed by Ellenberg were adopted. The data collected were analysed statistically using multivariate techniques.

pH and nitrate-nitrogen availability emerged as the most important components of soil nutrient regime. Most other nutrients were positively correlated with these. A single composite gradient of soil nutrient regime, incorporating all parameters, was defined. It was shown that the weighted mean site Ellenberg R value was correlated with this gradient with $r = 0.89$. The correlation could be enhanced to $r = 0.94$ by the use of internally-generated species indicator values. Humus type [mor, moder, mull] was also found to be related to site position on this gradient. Both vegetation species composition and humus type were thus shown to be effective for the field assessment of soil nutrient regime as defined. A division of the gradient into five classes of soil nutrient regime was proposed.

Declaration

I declare that this thesis has been composed by me and is a report of my own studies

[redacted]

"Est enim interpretatione vitiorum quaedam non aetate, quae nulla in ea intelligi potest, sed natura sua anilis, terra, et ideo infecunda ad omnia atque inbecilla."

For some soil exists which analysis of its vices shows to be not old in age, a term which conveys no meaning in the case of earth, but old in its own nature, and consequently infertile and powerless for every purpose.

"its est profecto, illa erit optima quae unguent sapiet --- talis fere est in novalibus caesa vetere silva, quae consensu laudatur."

It is certainly the case that a soil which has a taste of perfume will be the best soil. --- This is the kind of earth usually found in land newly ploughed where an old forest has been felled, earth that is unanimously highly spoken of.

"terram enim terra emendandi, ut aliqui praecipiunt, super tenuem pingui iniecta aut gracili bibulaque super umidam ac praepinguem, dementis operae est: quid potest sperare qui colit talem. Alia est ratio, quam Britanniae et Galliae invenere, alendi eam ipsa, genusque quod vocant margam:"

The plan of improving one soil by means of another, as some prescribe, throwing a rich earth on the top of a poor one or a light porous soil on one that is too moist and lush, is an insane procedure: what can a man possibly hope for who farms land of that sort. There is another method, discovered by the provinces of Britain and those of Gaul, the method of feeding the earth by means of itself, and the kind of soil called marl:

"namque non omnia in omnibus locis nasci docuimus, nec tralata vivere; hoc alias fastidio, alias contumacia, saepius inbecillitate eorum quae transferatur evenit, alias caelo invidente, alias sol repugnante"

In fact, we have shown that not all trees will grow in all places, or live if removed from one place to another; this is due in some cases to antipathy, in others to obstinacy, more frequently to the weakness of the specimens transplanted, because in some cases the climate is unfavourable and in others the soil is incompatible.

Excerpts from Pliny's Natural History [Books XVI & XVII] in translation by H. Rackham [Heinemann, London (1945)]

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ABSTRACT

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1. INTRODUCTION

1.1 Objectives of the research work undertaken

The work leading to the production of this thesis represents a part of an ongoing programme of development by the Forestry Commission Research Division [known as "Forest Research" since April 1997]. The objective of this wider project has been to evolve a system of Ecological Site Classification [E.S.C.] for future use in the planning and management of forests and woodlands in Great Britain. The overall work has been initiated and organised by Dr. Graham Pyatt of Woodland Ecology Branch, and has been in progress since the early 1990's [Pyatt (1995)].

The specific remit of the Ph.D. research work within this context was four-fold:-

1. To provide a quantified description of the range of soil nutrient regime [S.N.R.] occurring in British forests and woodlands, and to propose a basis for the division of that range into a suitable number of appropriately-defined classes for practical use.

2. To examine the potential utility of ground-layer vegetation species composition as an indicator of soil nutrient regime and to extend a methodology for its optimal use in recognising the defined soil nutrient classes in the field.

3. To examine the potential utility of forest humus type as a supporting indicator of soil nutrient regime and to extend a methodology for its optimal use in recognising the defined soil nutrient classes in the field.

4. To consider to what extent the distribution of the woodland communities and sub-communities as set forth in the National Vegetation Classification [Rodwell (1991)] can be related to the soil nutrient regime of the sites on which they are each observed to occur.

The work described in the remainder of this thesis was undertaken between October 1994 and September 1997 with the objective of meeting these requirements.

1.2 Existing systems of site classification in use in Great Britain

There is, currently, only one system of classification of site-type in widespread use for forest management purposes in Great Britain. This is a multi-factorial system, which has been developed over many years of experience by the Forestry Commission [Toleman & Pyatt (1974)], and is in use throughout the forest management operations of the Forest Enterprise. It also informs much practice in the privately owned sector of British forestry. It was evolved principally to meet the requirements of the first-rotation establishment phase of afforestation schemes. The factors examined in arriving at the classification of a site include (a) soil type, (b) soil moisture, aeration and available rooting depth, (c) elevation and slope gradient, (d) terrain characteristics, (e) topographical exposure and (f) climate [especially wind and frost risk-factors]. The system is used to classify sites in such a way as is of use in making decisions relating to species choice, ground preparation, supplemental nutrition, silvicultural regime during the rotation and harvesting methodology at its end. This could be described as an empirical approach to the recognition of physical features of the non-forested site, which will affect the conduct of establishment and silvicultural operations during the first rotation. The system is also used, in conjunction with growth models, to predict the yield of given tree species on a particular site.

Prior to the progressive adoption of the aforementioned system a variety of approaches had been used in the earlier phases of afforestation, particularly with regard to the matching of tree species to the planting site. These tended to consider the existing rather than the potential status of the site, as major manipulation [cultivation and supplemental nutrition] was not at that time as feasible or widely practised as it later became. A number of these approaches used the ground vegetation [usually of open land sites] to indicate site suitability for establishing particular tree species by planting. The most well known of these schemes was that set forth by Mark Anderson (1950) in *"The selection of tree species"*. The use of such methods tended to result in the planning of the earlier afforestation schemes being at a smaller spatial scale than became normal with the currently applied mode of site classification. Once the technical means of large-scale site amelioration became available, these earlier vegetation-based methods of site classification tended to be regarded as obsolete.

Co-existing with the above-described systems for classifying potential sites for afforestation, there have been a number of systems for classifying existing semi-natural woodlands. As the extent and productivity of such woodlands in Great Britain has been modest in recent times, these systems have mainly been developed with a view to their identification and conservation, rather than to assist management planning in a conventional sense. Some have been inspired by the classical Continental European approach to the phyto-sociological classification of vegetation communities [Braun-Blaunquet (1932)]. Arthur Tansley and his co-workers encouraged the adoption of a less formal approach to woodland classification in seminal publications such as *"Types of British vegetation"* [Tansley (1911)] and *"The British Islands and their vegetation"* [Tansley (1939)]. In recent years Peterken has put forward a classification of native woodland stand-types [Peterken (1993)] and Rodwell has co-ordinated the evolution of the National Vegetation Classification [N.V.C.] [Rodwell (1991), Whitbread & Kirby (1992)], which has 19 woodland communities with 59 sub-communities. This latter is now generally adopted for all native woodland conservation and management purposes, with Peterken's more involved system reserved for use in a few specific instances [e.g. *Tilia* and *Carpinus* stands] where the N.V.C. does not provide adequate coverage. Reference to the site-types supporting the N.V.C. woodland communities is restricted to a climatically based distinction between upland and lowland types and to recognition of acidophilous and basiphilous communities.

Hence, until the present time the two facets of classification (a) that of the site for new planting and (b) that of existing semi-natural woodlands have operated in some degree of isolation from each other.

1.3 Present motivation to seek an ecologically based approach

Since the mid to late 1980's, a number of factors have acted to stimulate the current programme of research endeavour aimed at evolving a new, ecologically based mode of site classification for use in Great Britain. They are as follows:-

- A considerable proportion of the Forestry Commission's earlier afforestation schemes are now reaching the end of the first rotation, and will thereafter require to be re-stocked. Hence, the focus has shifted from the planting of fresh open land sites to the promotion of renewed or continued forest cover on sites which have begun to assume certain of the characteristics of those found within more mature forests. This has stimulated interest in the use of managed natural regeneration as a re-stocking method, and in the use of a greater number of tree species.

- Such bare land planting as is occurring at present and for the foreseeable future will occupy a wider range of site types than the early afforestation schemes, including many more fertile and climatically favourable types. This again provides the opportunity to use a wider range of tree species and to practise a greater number of silvicultural systems.

- The objectives of forest policy as set out in government publications and statements has changed from one strongly focused on productivity and economic return to one emphasising the multiple benefits to be derived from forests and woodlands. This has in turn promoted a number of new trends in forest management practice, including:- (a) the creation of woodlands consisting of native species for reasons of conservation and restoration of biodiversity [Rodwell and Patterson (1994)], (b) a wish to reduce reliance on the clear-fell and re-plant silvicultural system and (c) an emphasis on ensuring that forest management systems can be shown to be sustainable on a multiple-rotation basis.

- A number of developments in scientific and technical disciplines have provided models of alternative approaches to forest site classification and also enhanced support techniques aiding their development and implementation [e.g. computerised Geographical Information Systems, satellite-derived climatic mapping and more sophisticated methods for the statistical analysis of ecological datasets].

The picture that emerges is one where the need for a new approach has coincided with the technical and scientific means by which one can be evolved.

1.4 <u>Criteria to be met by a system of Ecological Site Classification</u>

In order to meet the challenge of the factors set out above, the new system of site classification will have to improve upon the currently applied system either by replacement, modification or augmentation. Of these, it is expected that augmentation will be the primary mode of action. There is little evidence to suggest that any element of the current system is invalid, rather that it is incomplete when judged against the changed requirements described. The following specific areas can be identified where decision-making should be aided by the implementation of a new system:-

1. The selection of tree species either singly, in mixture, or as components of a vegetation assembly, which are ecologically suited to the site being used. [Suitability being defined as the ability to achieve good growth in volume and form, and thereby support both timber production and other objectives of management which may apply.] This may well encompass the prediction of achievable crop yield under given conditions.

2. The adoption of modes of silviculture from establishment to harvest which are consistent with the capacity of the site and capable of ensuring that the objectives set are secured.

3. The avoidance of the use of tree species, silvicultural methods or other management approaches which have an effect which may reduce site capacity (either immediately or over a number of rotations) to meet the objectives currently applied or any other reasonably foreseeable set of forest management priorities.

In addition, to be effective, the system must be able to be used by those responsible for making these categories of decisions throughout British forestry [subsequent to relevant dissemination and training]. This body of users possess a wide range of existing levels of familiarity with the skills which will be required to use a system of Ecological Site Classification [e.g. botanical identification, soil and humus type recognition and the use of computer-based land management-planning tools]. However, it is desirable that the system be presented to the user in such a way as to minimise the need, at least in the medium to long term, for the decision-making role to be deferred to specialists

2. BASIS OF THE ECOLOGICAL SITE CLASSIFICATION APPROACH

2.1 Literature review of approaches to forest site classification

Before setting out the principles upon which the proposed Ecological Site Classification [E.S.C.] scheme is based, I will review the literature relating to alternative means by which forest sites can be classified [Rennie (1963)].

Forest sites can essentially be classified by reference to one or more of three attribute sets:-

- The edaphic and climatic nature of the site itself, independent of its vegetation or stocking with trees.
- The potential timber yield of the site when stocked with an identified tree species or combination of tree species.
- The form and composition of the vegetation arising naturally on the site including tree species. This concept can be widened to include other components of a natural forest ecosystem.

Many systems of forest site classification appear to combine more than one of the above, but often by attempting to make statements relating to one of the attributes by deduction from a classification of another. For example a system based on classifying soil types and climate will often be used to make predictions with regard to tree yield on varying sites. When vegetation is involved in site classification, it is important to distinguish whether it is (a) the subject of classification *per se* [as in the third category above] or (b) being used as a surrogate or indicator of edaphic and/ or climatic factors. These defining features having been set out, a country-by-country format literature review will now be presented:-

Finland and Sweden

The earliest approaches to articulated forest site classification were developed in Scandinavia [notably Finland] at around the turn of the twentieth century. Prior to that time, site factors had doubtless been considered in decisions made by foresters, but the basis of such consideration was not set forth in a structured way in the literature. The system developed by Cajander in Finland [Cajander (1913, 1926 & 1949)] used the species composition of the ground vegetation [including bryophytes] to indicate site type in that country's pine-spruce-birch forests, often on peatland soils. The site-types defined appear to combine influences of both a hydraulic (soil moisture regime) and trophic (soil nutrient regime) character, with a view to making basic silvicultural prescriptions for the management of what are semi-natural forests. Natural regeneration is in widespread use as the method of re-stocking, after harvest, in these stands. Nieppola (1986) has reviewed the accumulated literature concerning the Cajander philosophy of site classification. Finnish site classification has evolved towards the use of ground vegetation as a direct indicator of site (yield) productivity [Lahti (1995), Nieppola (1993), Sarasto (1964), Viro (1961)]. This has been accompanied by an increasingly sophisticated classification of peat morphology for the purposes of forest management [Heikurainen (1972, 1979)]. Kuusipalo (1985) gives an example of the application of the current Finnish methodology in the country's southern upland area.

Similar methodologies are applied in Sweden, often on comparable site types [Hanell (1991)].

Belgium and France

Belgium and France have developed rather comparable systems of forest site classification with a strong ecological and phyto-sociological basis. These are applied in a wide variety of forest types, both coniferous and broad-leaved, which range from plantations to semi-natural selection forests. Both countries have a strongly developed system for using humus type as an indicator of site quality alongside ground vegetation, as was evident from the work of Duchaufour (1960) [See Figure 2.1.1]. In recent years the French system for using ground vegetation has been extensively developed and explained by Rameau, Mansion & Dume (1989, 1993) in their *"Guides ecologique illustre"* for the lowland, colline and montane altitudinal-climatic zones. Similarly, the humus type system has been set out by Brethes *et al* (1992) and Jabiol *et al* (1995) - this will be discussed in more detail in Chapter 4. Brethes (1989), Franc (1989) and Rameau (1992) have discussed the application of the French approach in different contexts.

The system in use in Belgium was described by Noirfalise (1984). Its application to species selection was explained by a Belgian government publication of 1991 [Anon], and its use in particular forest areas is illustrated by Maddelein *et al* (1994) and Weissen, Bronchart & Piret (1994).

It should be noted that, in both France and Belgium, soil quality is described in terms of soil moisture regime and soil nutrient regime [largely a measure of soil base status]. Ground vegetation and humus type are used, jointly, to indicate site position on both axes; displayed on an "edatopic grid".

Germany and Central Europe

The development of the disciplines of both phyto-sociological vegetation classification and forest soil science owe much to workers in Germany, Switzerland and Central Europe. This factor has acquired added significance with the initiation by Czech and Hungarian forest ecologists of the system of site classification in use in British Columbia, which will be discussed later. It is not therefore surprising that these countries display some of the most rigorous systems of forest site classification in current use.

Figure 2.1.1 <u>Duchaufour– site types, vegetation groupings & humus types</u>

TABLE II

FOREST HUMUS-TYPES AND ECOLOGICAL GROUPINGS (NORTH-EASTERN REGION)

INCREASING HUMIDITY →

DECREASING BASE RICHNESS ↓

Dry Medium		*Average Humidity*	*Humid Medium (+ or – aeration)*		*Temporary Water Saturation (Fluctuating Water Table)*	*Permanent Water Saturated (Surface Water Table)*
XEROMORPHIC CALCIFEROUS MODER Sesleria coerulea Festuca duriuscula	CALCIFEROUS XEROMULL Carex montana Brachyp. pinnatum	EUTROPHIC OR CALCIFEROUS MULL Mercurialis perennis Brachyp. sylvaticum	ACTIVE EUTROPHIC MULL Ficaria ranunculoides Glechoma hederacea	EUTROPHIC HYDROMULL Spiraea aruncus Impatiens noli tangere	EUTROPHIC AND MESOTROPHIC ANMOOR Tall Carex Juncus spp.	EUTROPHIC AND MESOTROPHIC PEAT Phragmites communis Iris pseudacorus
SANDY MODER Corynephorus canescens Cladonia sylvatica		FOREST MULL Melica uniflora Asperula odor. Festuca sylv.	HYDROMULL Athyrium filix-femina Mulgedium alpinum			
XEROMORPHIC ACID MODER Cladonia sylvatica Leucobryum glaucum		FOREST MODER Deschampsia fl. Luzula albida Hypnum lorcum	HYDROMODER (1) Blechnum spicant Mastigobryum trilobatum (2) Molinia coerulea		ACID ANMOOR Molinia coerulea	ACID PEAT Eriophorum vaginatum Trichophorum coespitosum Sphagnum spp.
XEROMOR Calluna vulgaris Hypnum schreberi		MOR Vaccinium myrt. Dicranum scop.	HYDROMOR Vaccinium uliginosum Listera cordata Polytrichum commune			

N.B.—The optimum of biological activity (mineralization and humification) is located at the level of the active eutrophic mull—eutrophic hydromull: it decreases along the diagonals, towards the opposite angles: Xeromor, acid peats.

Taken from: **Duchaufour (1960)**

Both Germany and Switzerland are divided into so-called "growth regions" within which macroclimate is assumed to be fairly uniform, although microclimate is influenced by topography. For each of these entities a complex system has been evolved for assessing soil type, parent material and moisture regime, relying on the use of ground vegetation "indicator species groups" and in some cases humus type and tree yield. The definition of the "indicator species groups" is based on the classical phyto-sociological approach. Sebald (1964) explains their use in Baden-Wurttemberg [Upper Neckar growth region]. Klock (1970) provides a more general treatment. Csapody *et al* (1963) describe the use of a similar approach in Hungary. See also Rambouskovia (1984).

United States and Canada [excepting British Columbia]

A detailed description of the system of forest site classification in use in British Columbia, Canada will be reserved for section 2.2 below, due to its close affinity to the proposed E.S.C. scheme for Great Britain. Other North American schemes will be described here.

Both the United States and Canada now have in use a number of regional systems of ecologically based forest site classification. In the United States these have been evolved over the past twenty years to respond to demands for multi-objective management in State forests, of a kind which are familiar in Great Britain as described in Chapter 1. Prior to this period the system in use was focused strongly on the assessment of site-yield potential [site-index] from a production-forecasting viewpoint [Carmean (1975)]. From the mid-1970's onwards the emphasis began to shift initially to the classification of forest ecosystems on vegetative grounds, and latterly to the classification of forest sites on the basis of abiotic environmental parameters. This trend was reflected earlier in the climatic work of Daubenmire (1956) in the Pacific Northwest. The Harvard Forest in Massachusetts saw important work on the use of vegetation for site diagnosis [Walker (1975)], and the theme was taken up by Lee & Spyholt (1974). A system of regional-scale eco-climatic units was described by the

US Forest Service [Bailey (1978)], and a number of site-scale systems within these regions have now been developed:- for Wisconsin by Kotar and Burger (1989), for the Pacific Northwest by Franklin (1980) and for New England by Fincher & Smith (1994). Other systems continue to be evolved. A synthesis of the concepts employed was provided by Barnes *et al* (1982). An important influence guiding these developments has been the strong demand for holistic "ecosystem management" in US Forest Service forests. This has favoured an approach based on classifying whole forest biomes with a view to non-intervention/ conservation-inspired regimes of management.

In Canada also, a number of Provincial systems of ecologically based site classification have been developed. These have tended to evolve quite separately, but have converged on a model with many common elements. In particular they are used to produce detailed site-related prescriptions for active forest management, to a greater degree than in the United States. An overview was provided by Burger (1972). Outside British Columbia the longest-established systems are those for Ontario [Hills (1952), Hills & Pierpoint (1960), Sims & Uhlig (1992), Sims, Mackey & Baldwin (1995) and for Quebec [Lemieux (1963)]. Jones *et al* (1983) and Gagnon & MacArthur (1959) provide specific examples of the application of these approaches. They share the major features of regional-scale eco-climatic units [diagnosed mainly by naturally occurring forest types] and site-scale units [diagnosed mainly by ground vegetation].

Great Britain

As indicated in the introduction, the use of ground vegetation to diagnose forest site type in Great Britain has had relatively restricted application in the past. The work of Anderson (1950) *"The selection of tree species"*, was a major exception to the rule. A system of site types to be recognised by major vegetation groupings was set forth, in a manner that must be considered in the tradition of Cajander [See Figures 2.1.2. & 2.1.3]. The resolution of the system was not especially great, but the work did

Figure 2.1.2 Mark Anderson – site types and vegetation communities

Table of Waste Land Communities

Fertility-Class	Dry 1	Moist 2	Wet 3a	Wet with Peat 3b
A	Dry Grass-herb	Moist Grass-herb	Grass-rush (Hard Rush)	Willow-reed
B	Dry Grass	Fern	Sedge	Soft Rush
C	Grass-heath	Rush-grass (Jointed Rush)	—	*Molinia*
D	*Erica cinerea*	*Nardus-Molinia*	—	Cottongrass
E	*Calluna*-heath	*Vaccinium*	—	*Myrica*
F	Lichen	*Erica tetralix*	—	*Sphagnum-*

Taken from: **Anderson (1950)**

Figure 2.1.3 Mark Anderson – Selection of Tree Species

TABLE OF FUTURE STAND UNITS OR GROUPS OF SPECIES

FERTILITY-CLASS	DRY *Hardy*	DRY *Tender*	MOIST *Hardy*	MOIST *Tender*	WET (*a*) *Hardy*	WET (*a*) *Tender*	WET (*b*) *Hardy*	WET (*b*) *Tender*
A	Wych elm Lime Whitebeam Cordate Alder Austrian pine Corsican pine	Beech Horse chestnut	Elms Grey poplar Aspen Grey alder Willows Lime	Sycamore Ash Beech Walnuts Nordmann's silver fir	Grey poplar Alders Aspen Scots pine	Ash	Alders Willows Poplars Scots pine	Norway spruce
B	Elms Lime Birch Turkey oak Japanese larch Corsican pine European larch	Ash Beech Sycamore Horse chestnut	Aspen Hornbeam European larch Japanese larch Scots pine Weymouth pine Thuia Lawson's cypress	Oak Sweet chestnut Beech Cherry Douglas fir Silver firs Spruces Tsuga	Alders Willows Thuia	Norway spruce	Alders Poplars	Norway spruce

FERTILITY-CLASS	DRY *Hardy*	DRY *Tender*	MOIST *Hardy*	MOIST *Tender*	WET (*a*+*b*) *Hardy*	WET (*a*+*b*) *Tender*
C	Birch Japanese larch European larch Scots pine Corsican pine Monterey pine	Sessile oak Sweet chestnut Beech	Birch Aspen Alders Scots pine Thuia Lawson's cypress	Oak Spruces Tsuga Silver firs	Aspen Alders Willows Thuia	Spruces
D	Birch Scots pine European larch Japanese larch	Sessile oak Douglas fir	Aspen Scots pine	Spruces Tsuga *Abies procera*	Pubescent birch Alders	Sitka spruce
E	Birch Scots pine	Red oak	Birch Rowan Scots pine European larch	Red oak Douglas fir Norway spruce Sitka spruce	Pubescent birch Black alder	Sitka spruce
F	Scots pine Shore pine Mountain pine		Pubescent birch Shore pine Mountain pine		Mountain pine Shore pine	

Taken from: **Anderson (1950)**

influence the planning of Forestry Commission and other forests in the period up to approximately 1960. Many of the forests planned under this regime have now reached maturity and are aesthetically attractive.

The major strand in the development of forest site classification in Great Britain, as alluded to before, has been the empirical relation of physical site features, usually directly measured, to the success of establishment and volume yield performance of plantation crops. The features considered most often have been climate [especially exposure to the risk of wind-throw] and soil moisture regime as a constraint on rooting depth and hence stability. Soil nutrient regime has been taken into account, but usually only where its deficiency might suggest that the crop would respond to artificial fertilisers. The main diagnostic tools used have been direct measures of climatic variables, depth to the soil water table and key soil physical and chemical variables. The use of soil type has been foremost in the field diagnosis of both soil moisture regime and soil nutrient regime, despite its ambiguity, certainly in respect of nutrients, other than at the extremes of the range. These principles have led to the evolution of a system of abiotic site-classification by the Forestry Commission over a long period [Toleman & Pyatt (1974) and Pyatt (1977)].

There has been a substantial body of "site-yield" work, which has attempted to isolate those abiotic factors of the site, which have the greatest influence on the yield of commercial conifer species. This began with the work of Malcolm (1970), who explored the impact of a number of climatic and soil variables [directly measured] upon the yield of plantations of *Picea sitchensis* [(Bong.) Carriere] in Scotland. It was concluded that climatic variables [mediated by elevation] were much more significant in their yield impact than were those relating to the soil. This insight was strengthened in more recent work together with Worrell [Worrell (1987) and Worrell & Malcolm (1990)], which moved further into a yield-prediction mode, with relation to this particular species. The prediction of the yield of *Picea sitchensis* on "better-land" sites was explored by MacMillan (1991), and Allison, Proe & Matthews (1994) explored the use of Geographical Information Systems for this purpose. Comparable work has been undertaken for *Pseudotsuga menziesii* [(Mirbel) Franco] by Tyler, MacMillan & Dutch (1995). A wider range of species, including native broadleaves, have recently been subjected to a site-yield survey by the Forestry Commission's Mensuration Branch, with a view to lowland plantation schemes on the more fertile soils. However the range of measured soil nutrient variables was restricted. It is intended to extend this work by a more detailed site-yield study for *Fraxinus excelsior* [L.]

However, both before and after the publication of Anderson's *"The selection of tree species"*, there has been a thread of opinion that a greater emphasis should be placed on the capacity of ground vegetation to reveal information about soil conditions in British woodlands. This was encouraged by the development of woodland vegetation ecology in Britain [Tansley (1943)]. Pre-war work at the new forests of Bin and Clashindarroch, in Aberdeenshire, attempted to relate open-land vegetation communities to the fertility of the underlying soil [Muir & Fraser (1939)]. These themes were taken up at Bangor by Hetherington & Page (1965); and also, with particular relation to *Fraxinus excelsior,* by Gordon (1964). However, most work on forest vegetation classification in Great Britain has not attempted to explore the relationship with site fertility in any great depth, being mainly interested in the structure of plant communities [Bunce (1982, 1989), Peterken (1993) and Rodwell (1991)]. Peterken did record soil pH for the survey sites used in the development of his classification of stand types, but the National Vegetation Classification [Rodwell (1991)] only refers to acid and base-rich sites in a qualitative way.

2.2 B.E.C. in British Columbia: a model for Ecological Site Classification

As has been stated above, there is a limited amount of experience of the application of ecologically based forest site classification in Great Britain. Such as there is, for example Anderson's scheme, tends to be earlier work, and hence does not take account of more recent developments in ecological understanding. For this reason it was decided by the Forestry Commission to look overseas for working models to inform the development of a new system for this country.

For reasons of climatic and commercial tree-crop similarity, it was thought likely that the scheme developed for use in British Columbia might prove to be one of the most relevant. This system is known as Biogeoclimatic Ecosystem Classification [B.E.C.], and has been under implementation in the Province for 20-25 years, having taken some 10 years to develop - making it one of the longest-tested systems in use in North America. A valuable feature of this scheme is that it incorporates much of the rigorous analysis characteristic of Continental European phyto-sociology and forest soil science, by virtue of its having been developed by forest ecologists from Czechoslovakia who emigrated after the Second World War [Krajina (1965)].

In principle the system operates at two scales of analysis, those being the region and the site [MacKinnon *et al* (1992), Pojar *et al* (1987)]. In practice the regional scale is further resolved into sub-regions ["zones"]. The regions and zones are units of identifiably consistent forest type, influenced primarily by climatic factors. In a landscape containing large tracts of natural forest, canopy species composition can effectively be used to act as a proxy for the climatic regime once a general pattern is recognised [Meidinger & Pojar (1991)]. At the site level units of identifiably similar ground vegetation and humus type are recognised, influenced primarily by soil nutrient regime and soil moisture regime [Kabzems & Klinka (1987), Klinka *et al* (1990)]. These in turn are products of geology, topography and, to a certain extent, forest type [Klinka *et al* (1995)].

One of the most important features of the B.E.C. scheme is the explicit definition of underlying site quality in terms of soil nutrient regime and soil moisture regime, within a climatically determined region. This information is displayed visually for each region in the form of an "edatopic" or soil quality grid, with soil nutrient regime and soil moisture regime ordinated orthogonally [See Figure 2.2.1]. Hence the use of ground vegetation is given a clear objective- the recognition of classes of soil moisture and soil nutrient regime. The B.E.C. scheme describes the ground vegetation in terms of "indicator species groups", a somewhat looser concept than the classical communities or associations of Continental Europe. Humus type is used as a subsidiary indicator of soil nutrient regime in particular, following a visually recognised taxonomic key [Green *et al* (1993), Klinka *et al* (1981), Lowe & Klinka (1981), Qian & Klinka (1995)]. The use of both ground vegetation and humus type is assisted in practice by a set of "field guides to interpretation", matched to each region or zone as described above [Houseknecht *et al* (1987), Klinka *et al* (1989), MacKinnon *et al* (1990), Pojar *et al* (1982)]. In turn, a set of forest management recommendations is set out, based upon the site diagnoses produced [Klinka *et al* (1984), Stanek (1966), Wang & Klinka (1995)].

2.3 <u>Factors influencing adoption of B.E.C. principles in Great Britain</u>

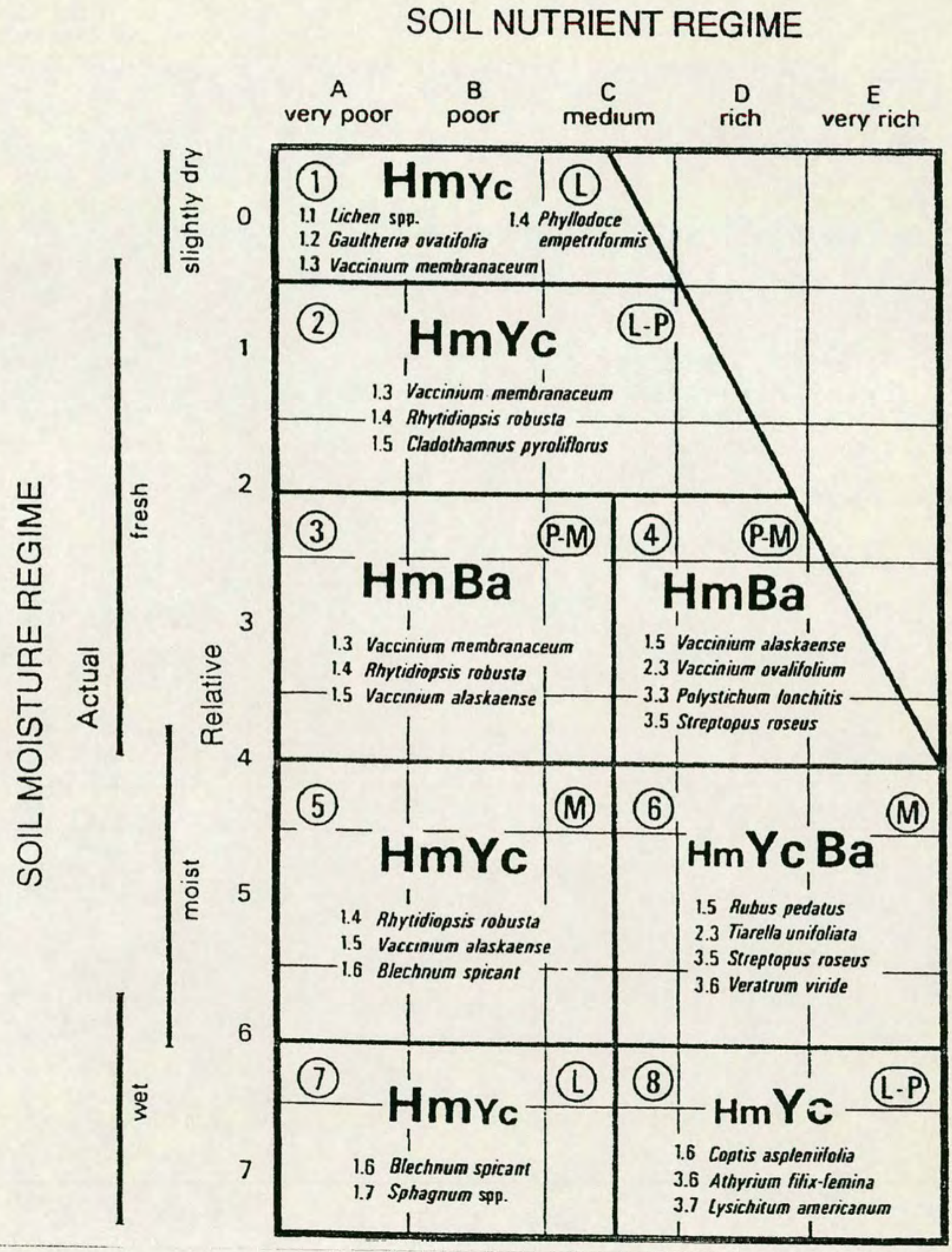
Having identified in Chapter 1 the objectives for developing a new system of ecologically based site classification for Great Britain, a suitable model has now been cited in the British Columbian B.E.C. scheme. This provides a set of key principles which, it is thought, should be adopted in the design of a system for this country. These can be summarised as follows:-

1. The definition of regional scale units on grounds of macroclimate.

2. The definition of site scale units on grounds of soil conditions.

3. The use of ground vegetation to indicate soil conditions.

Figure 2.2.1. B.E.C. edatopic [soil quality] grid



Key – Canopy species
Hm = Mountain hemlock
Yc = Yellow cedar
Ba = Sub-alpine fir

Key – Productivity classes
L = Low
P = Poor
M = Medium

Taken from: MacKinnon, Meidinger & Klinka (1992)

4. The use of humus type as a supporting indicator of soil conditions.

5. The use of a soil quality grid to display the soil information

6. The preparation of management guidelines based on the region and site type.

However, a number of features of ecological and forestry conditions in Britain require modifications to be made to the way in which the system is operated, as compared with British Columbia, namely:-

- Regional scale forest vegetation is largely absent from this country as a result of anthropogenic modification, and is therefore not available for use in the delineation of the larger-scale, climatically determined classification units. Hence direct measures of governing climatic parameters will have to be used for this purpose.

- The species composition of the ground vegetation in many British forests and woodlands is likely to manifest evidence of disturbance and hence may not conform reliably to recognisably indicative phyto-sociological communities. Hence, an alternative mode of use of the ground vegetation to indicate soil conditions will have to be proposed and tested.

- The range of humus types found in British forests is thought to be wider than is the case in British Columbia due to a number of factors. This may imply the need to extend the coverage of the humus form taxonomy mentioned above.

- A different pattern of forest management practices, skills and experience in Britain is likely to give rise to additional issues with regard to the implementation of such a site classification scheme in this country. These may need to be reflected in the design and complexity of both the system itself, and the planning of its promulgation.

2.4 The proposed Ecological Site Classification scheme for Great Britain

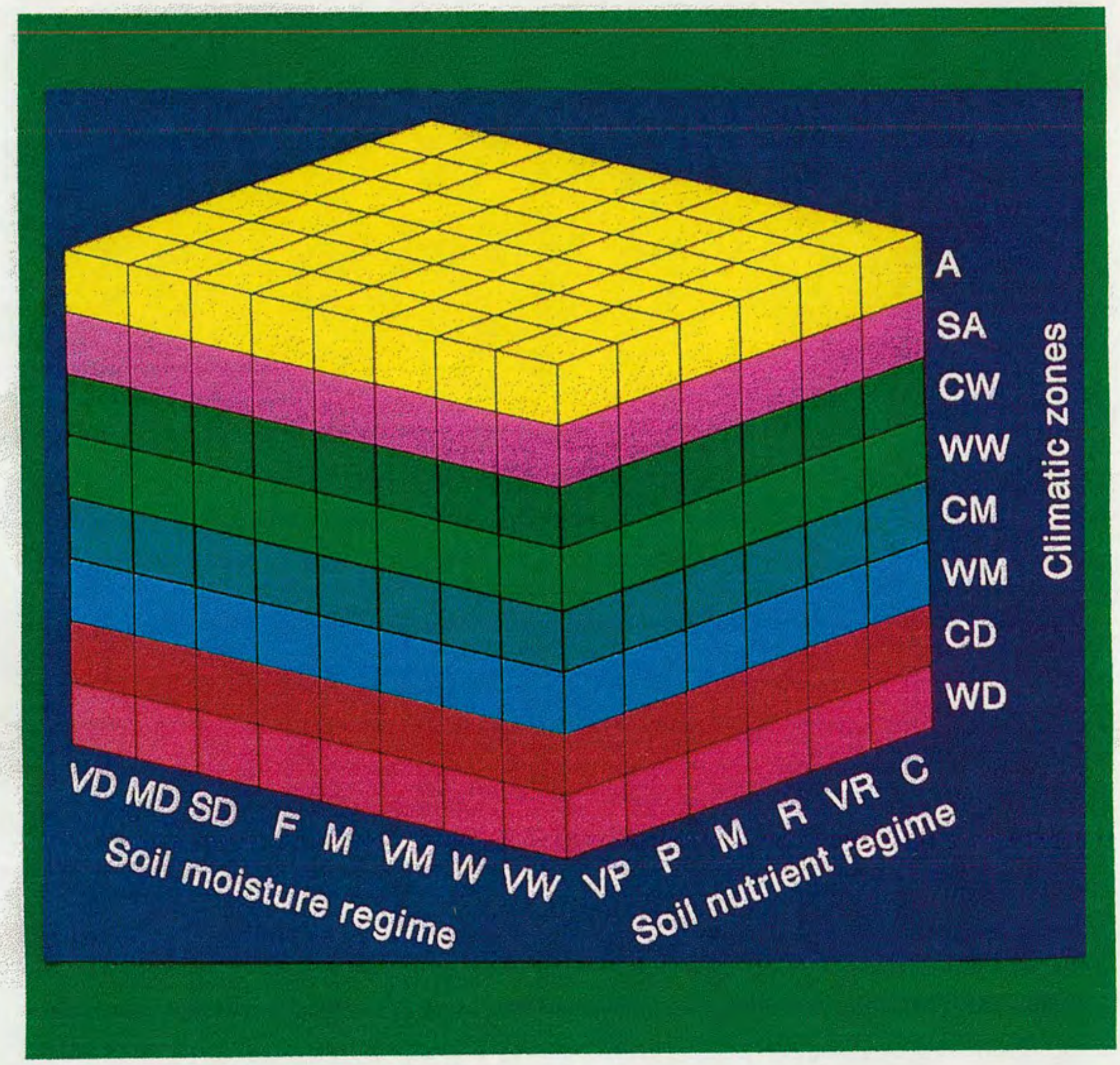
Classification of climate and wind-throw hazard

The proposed Ecological Site Classification scheme for Great Britain essentially comprises a simultaneous tri-axial description of (a) climatic regime, (b) soil moisture regime and (c) soil nutrient regime. [Pyatt (1995,1996), Pyatt & Suarez (1997)] [See Figures 2.4.1. & 2.4.2.]

The characterisation of climatic regime, for reasons described above, must be tackled through direct meteorological study, rather than by placing reliance on indication by expressed forest vegetation at the regional or landscape scale. This process will essentially divide into two components (a) a quantitative description of the climate in terms of growth-determining variables and (b) an empirical risk-assessment for wind-throw derived from climatic and topographic site features.

In the former case, growing-season warmth [as defined by accumulated temperature above a growth minimum of 5.6°C] and summer drought intensity [as defined by Penman-Monteith potential moisture deficit] are taken to be the key parameters. For the development of these concepts see Bendelow & Hartnup (1980), Birse & Dry (1970), Birse & Robertson (1970), Birse (1971), Green (1963, 1964), Gregory (1954), Griffiths (1966), Hallett & Jones (1993), Odin, Eriksson & Perttu (1983) and Trewartha & Horn (1980). For operational convenience in forest management, it is proposed to classify the former as either cool or warm and the latter as dry, moist or wet. The meteorological data required to make these assessments are readily available for Great Britain from the Meteorological Office, and can be interpolated to take account of elevation and topography by the use of a computerised digital terrain

Figure 2.4.1. E.S.C. site quality cube



Key

Soil moisture regimes

VD = very dry
MD = moderately dry
SD = slightly dry
F = fresh
M = moist
VM = very moist
W = wet
VW = very wet

Soil nutrient regimes

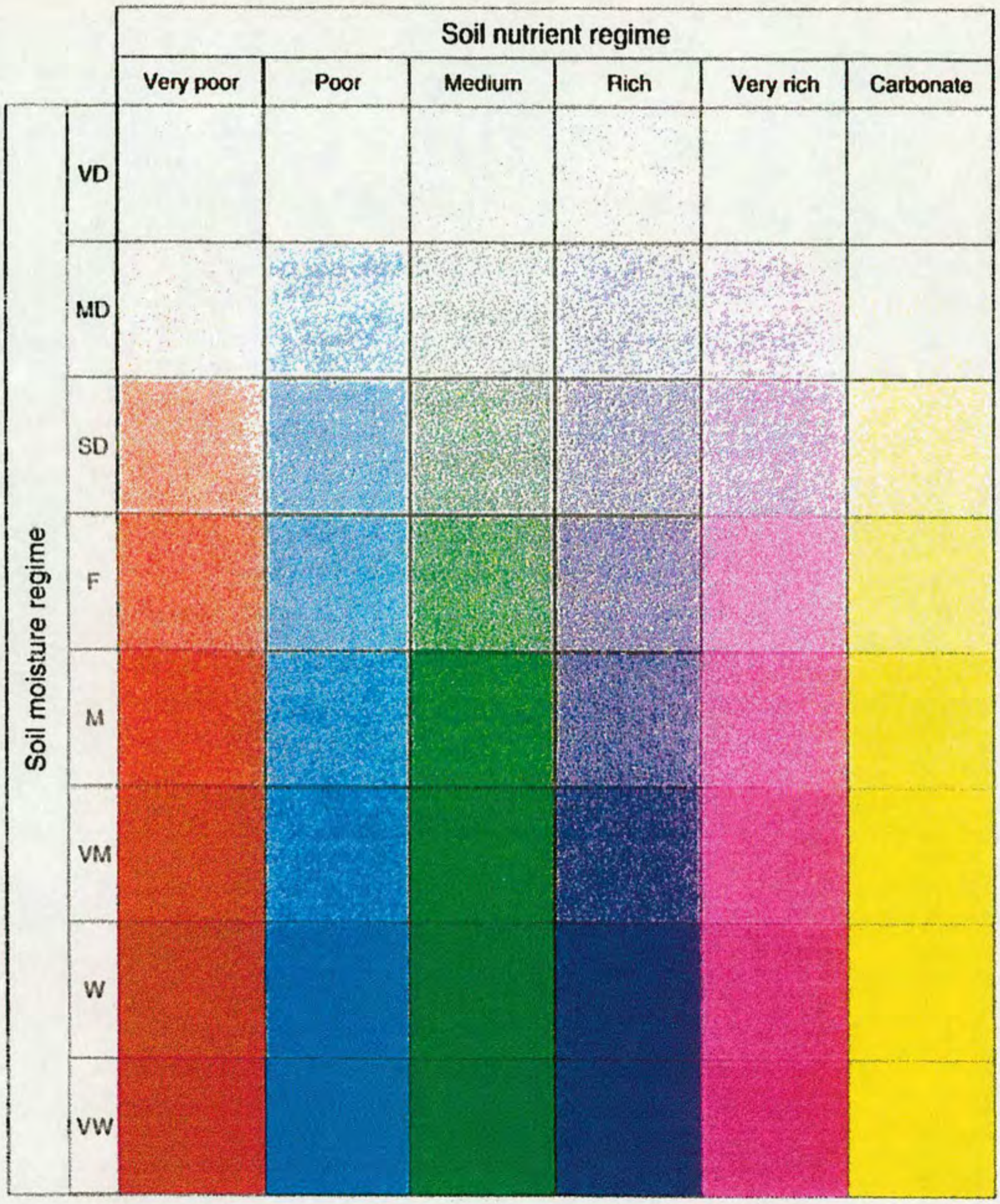
VP = very poor
P = poor
M = medium
R = rich
VR = very rich
C = carbonate

Climatic zones

WD = warm dry
CD = cool dry
WM = warm moist
CM = cool moist
WW = warm wet
CW = cool wet
SA = sub-alpine
A = alpine

Taken from: Pyatt (1995)

Figure 2.4.2 <u>E.S.C. soil quality grid</u>



SMR	VW	W	VM	M to VD
winter w.t.	0-20 cm	20-40 cm	40-60 cm	>60 cm

VD=very dry
MD=moderately dry
SD=slightly dry
F=fresh
M=moist
VM=very moist
W=wet
VW=very wet
w.t.=water table

Taken from: Pyatt (1995)

model [D.T.M.]. The concept of "continentality" or its inverse "oceanicity" may also be brought into the climatic classification [Conrad (1946)].

The assessment of forest plantation wind-throw hazard is a well-developed technique in this country. The original work by Miller (1985) made use of the concept of topographical exposure "TOPEX" [Pyatt (1977)] to assess the hazard potential. This has been further refined in recent years by the use of tatter-flag data in conjunction with Digital Terrain Models [Bell, Quine & Wright (1995), Mackie & Gough (1994) and Quine & White (1993, 1994)].

Classification of soil moisture regime

The second axis of the classification, soil moisture regime, raises two related questions (a) which aspects of soil moisture regime are to be classified, and (b) how is their status to be assessed in the field. For freely draining soils, it is considered that the severity of any drought in the summer is the most important feature, and a range of four classes from fresh to very dry is proposed, describing the extent of any soil water deficit. For soils of impeded drainage, the active feature is the minimum depth of the water table in the winter period, due to its effects on the available rooting depth and resulting tree crop stability. Such soils will be classified from moist to very wet, again in four classes [Pyatt (1995), Pyatt & Suarez (1997)].

Soil moisture regime can be assessed by one of three methods:- (a) moisture content and soil water potential measures made in the laboratory, [Robin & Thomasson (1977), Thomasson (1979)]; (b) the use of vegetation as an indicator of conditions; or (c) the use of the climatic moisture deficit adjusted for a soil moisture storage term. Of these the first is essentially impractical for operational purposes due to its cost and inconvenience. The use of vegetation to indicate soil moisture regime gives a broad band estimate, but has not been shown to be sufficiently precise for use in British conditions. Hence, the method adopted for freely-draining soils will be as follows:-

[i] determine the climatic moisture deficit [M.D] - (Penman-Monteith potential evapotranspiration for grass, less rainfall for the summer period) [Green (1963, 1964)]; [ii] estimate the available water capacity [A.W.C.] of the soil, by means of a textural key applied to a described profile [Brais & Camire (1991) and Hall *et al* (1977)] and [iii] use these two in conjunction to estimate the driest condition the soil will display in the summer, on the basis that it ends the winter fully charged with moisture. If the soil is of impeded drainage the minimum winter water-table depth should be determined by bore hole measurement or estimated by inspection of the soil profile colouration.

Classification of soil nutrient regime

The remainder of this thesis will concentrate on the development of the definition and classification of soil nutrient regime to be used as a component of the Ecological Site Classification, and on the potential for the use of ground vegetation and humus type in its field assessment.

Two important aspects of the topic of soil nutrient regime must be considered from the outset:-

- Why is it important to include a classification of soil nutrient regime in the wider Ecological Site Classification scheme?

- What features of soil nutrient regime should form the basis of its definition?

There are four main issues suggesting that it is essential to include a classification of soil nutrient regime:-

- The influence of soil nutrient regime on site suitability for establishing a particular commercial tree crop, and on its subsequent timber yield.

- The influence of soil nutrient regime on the form and species composition of naturally arising woodland vegetation communities.

- The possibility that certain features of active forest management [including species selection], may have an adverse effect on the soil nutrient regime of a site. This can occur by complete removal of nutrients (for example by harvesting, leaching or soil erosion), or more insidiously by their incorporation into organic chemical compounds in which they are no longer available to the tree crop. Such factors obviously militate against the sustainability of those practices, and certainly their desirability.

- Conversely that the use of other practices, especially in terms of species choice, can result in improvements in the soil nutrient regime.

Soil nutrient regime is a complex of many different degrees of availability of particular nutrients, and it is not self-evident that the same nutrients are of importance for each tree species or native woodland type. However, it will be a central hypothesis of the work that follows that a set of nutrient measures can be selected which explain the majority of the impact of soil nutrient regime on forest development. Further that the species composition of the ground vegetation and the humus type can be effective tools in assessing the availability of these nutrients in the forest.

Two main approaches suggest themselves as to how to move towards an appropriate quantified definition of forest soil nutrient regime:-

- Measure a wide selection of soil nutrient variables for a range of forest soils and base the definition upon those explaining the greater proportion of the internal variation. The ability of ground vegetation to predict the status of these would then have to be demonstrated.

- Measure soil nutrient variables as above, but base the classification upon those explaining the greater proportion of the variation in species composition of the ground vegetation. In this case ground vegetation is being used as a "surrogate" for the response of individual tree species and the composition of complete natural woodland ecosystems. Hence the predictive capacity of ground vegetation is implicit.

Both approaches will be adopted in the analysis of the field data collected. This is essentially a matter of the utilisation of different multi-variate statistical techniques.

It is anticipated that, once defined, the main soil nutrient continuum will be divided into five classes [very poor, poor, medium, rich and very rich], with the possibility of a sixth class to cover soils derived from carbonate materials. The latter are known to display counter-valent nutrient variation which is absent from most siliceous soils. The number of main-sequence classes is essentially a matter of judgement as to how fine the classification should be in the light of operational requirements and ease of adoption, rather than an emergent property of the soil chemistry itself.

3. DESCRIPTION OF THE FIELD SITES STUDIED

3.1 Basis of selection of field sites

To meet the requirements of the project, it was decided to carry out simultaneous sampling of soil chemistry, ground vegetation species composition and humus type at a wide range of forest sites in Great Britain.

The methods adopted for all elements of the sampling, at each individual site, will be set out in succeeding chapters; the aim here is to describe the way in which the sites themselves were selected. Five main issues had to be decided upon in advance:-

- The number of sites which could be included in the project
- When these sites should be sampled
- Those elements which the sites should have in common
- Those attributes of site-type for which a variate range should be covered
- The scope for combining site selection with other research projects

The first two issues were strongly related, in that the overall number of sites included was essentially governed by the time available for field sampling work and for the subsequent chemical analysis of soil samples in the laboratory. The greater the number of sites included, the clearer might be the demonstrated relationships, so there were no logical grounds for restricting the number of sites to a level below that dictated by logistical considerations.

It was decided at the outset that field sampling work should only be carried out in the period from mid-May to mid-October for two reasons:- (a) the ground vegetation would not be expressed sufficiently outside that season for it to be sampled effectively and (b) there might be natural fluctuations in the levels of certain soil nutrients associated with the occurrence of freeze/ thaw effects outside that season, and with the fall of deciduous tree and plant litter later in the autumn. As the time required for laboratory analysis was similar to that for field sampling, this was a convenient division of the year, with the winter season used for the former. The sampling work at each site required a full day, so the number of sites sampled was essentially the number of working days available during the field season. As many of the sites were at a distance from Edinburgh, it was found that about half the field season could be spent on site, with the remainder required for initial soil sample processing and the maintenance of field equipment. Over the two field seasons of 1995 and 1996 it was possible to sample 70 sites as reported later. These were mainly included in tours to different parts of the country, covering from five to eight sites over a similar number of days, with a smaller number of single day visits to more local sites.

It was required that all sites should have the following features:-

- Established tree cover.
- Sufficient vascular ground vegetation to permit an effective survey of species composition [at least 50% ground cover].
- A sufficiently large area of apparently uniform tree crop, ground vegetation type and soil type.
- That they should be accessible both legally and physically. Given the equipment in use this meant that a vehicle [usually a normal car with trailer] should be able to reach a point within 100m of the site, from which safe pedestrian access could be gained.

It was decided that the total group of sites surveyed should cover:-

- The major soil types in current use for forestry in Great Britain. Minor soil types could not all be included in a project of this scale. Deep peat soil types were not sampled because the future use of such sites for forestry is likely to be limited by environmental considerations.

- The common ground vegetation species complexes occurring in British forests. Rarer types could not all be included. The results of soil chemical analysis from the first season were used to identify target parts of the implied soil nutrient range for sampling in the second field season.

- The major geological parent materials underlying British forests. Minor geological types could not all be included.

The selection of individual sampling sites was determined by the above requirements, but was also influenced by the logistical constraints within which the sampling work was carried out. In particular, it was not feasible to use a formalised method of site selection to ensure a uniform intensity of coverage of the soil and vegetation conditions found in British forests. For example, the requirement for well-developed ground vegetation restricted the coverage of poor, wet upland sites where forest stands tend to be young crops of shade-casting species. Although attempts were made to sample soils that were shallow to carbonate materials, it proved difficult to locate such sites that were suitable on other criteria. These factors may impose restrictions on the extent to which certain specific categories of site can be described within the classification finally produced. As discussed in Chapter 8, these issues will be addressed in future work.

An additional factor influencing the selection of the study sites was the availability of information relating to crop yield. It was desirable to have the opportunity to compare the nutrient status of the sites with the yield of the standing tree crop. It was not possible to carry out stand measurement work during the time spent at each site, due to the time required for the other sampling work. Hence it was relevant to identify sites where this had been carried out previously.

All Forest Enterprise stands have an assigned General Yield Class [G.Y.C.] on the Sub-compartment Database maintained by the Forest District, based on the use of the height-age yield curves developed by F.C. Mensuration Branch. The development of these curves involved the establishment of a large number of Permanent Sample Plots [P.S.P's] throughout the Commission's forest estate, which are measured on a five-yearly cycle and subjected to standard thinnings. These produce direct measures of the yield of those individual stands, and, in addition, measures of height increment at regular intervals. The decision was taken to base the majority of the site sampling work in these P.S.P's which would have the greatest amount of available measurement data. In addition these offered the advantage of being well-defined research Plots which could be identified in advance as to location, crop species, age, geology and soil type.

In practice the planning of each main field tour consisted of the selection of a suite of such plots in a geographical region, to provide both "first choice" sites and back-ups. The sites preferred carried older crops of broad-leaves, pine and larch, which would allow sufficient light through the canopy to permit the development of ample ground vegetation. Young crops of species such as spruce and fir were eliminated as they were rarely found to have well developed ground vegetation, but it was possible on occasion to include mature stands of these species.

A minor proportion of the sampling took place outside P.S.P.'s, under three circumstances:-

- It was decided to include a small number of sites in semi-natural woodlands under the management of Scottish Natural Heritage.

- A small number of sites were included, although not P.S.P.'s, because of value to other FC research projects or pre-recognised ecological interest.

- On occasion a non-P.S.P. Forest Enterprise stand had to be selected for a day's work if a P.S.P. had been found to be unsuitable and no other was sufficiently nearby. This could mean working a site adjacent to the P.S.P. for reasons, for instance, of better access or more intact vegetation.

Of the 70 sites included in the programme, all but 2 have available G.Y.C. data, and over 50 have direct measures of yield and of height increment.

Whilst the use of the P.S.P. network for the majority of the site selection proved valuable, a number of weaknesses in the information held about these plots were highlighted. For a significant proportion of the plots the location and soil type information was inaccurate and had to be revised in the light of observation in the field. In addition, the quality of botanical information recorded by the surveyor, at the time of the re-measurements of the stand, had shown a marked decline since the earlier decades of the plot recording work. In some cases, a valuable opportunity to chart the history of vegetation development under the growing crop had been missed as a result. However in many cases there were recorded details of interest, and these are displayed in Figure 3.4.1.

3.2 Site descriptions and details

At each site the following information was recorded in a preliminary site assessment prior to commencing sampling of the soil and vegetation:- (a) location (OS grid reference), (b) elevation, (c) aspect (by cardinal compass points), (d) slope gradient, (e) slope shape, (f) relative position on slope, (g) crop species and (h) any other notable features. The following items of information were obtained from Forestry Commission records or other sources:- (i) solid geology, (j) year of establishment of the crop if planted, (k) General Yield Class of crop and (l) provisional Ecological Site Classification climatic zone and soil moisture regime

Summary site descriptions are presented in Figure 3.2.1. Further details are contained within the individual site description sheets in Appendix 1.

3.3 Photographic record of sites sampled

See figures 3.3.1 to 3.3.7

Key to Figure 3.2.1

CPT/ PSP

CPT = Compartment [standard Forestry Commission management unit]

PSP = Permanent Sample Plot [part of a compartment set-aside for research work]

Crop

SP = Scots pine [*Pinus sylvestris*]

JL = Japanese larch [*Larix kaempferi*]

NS = Norway spruce [*Picea abies*]

SS = Sitka spruce [*Picea sitchensis*]

GF = Grand fir [*Abies grandis*]

EL = European larch [*Larix decidua*]

BE = Beech [*Fagus sylvatica*]

OK = Oak [*Quercus petraea/ robur*]

SYC = Sycamore [*Acer pseudoplatanus*]

AH = Ash [*Fraxinus excelsior*]

DF = Douglas fir [*Pseudotsuga menziesii*]

HL = Hybrid Larch [*Larix x. eurolepis*]

CP = Corsican pine [*Pinus nigra v. maritima*]

BI = Birch [*Betula pubescens/ pendula*]

PP = Ponderosa pine [*Pinus ponderosa*]

Climate

CM = Cool moist

CW = Cool wet

WD = Warm dry

WM = Warm moist

WW = Warm wet

Figure 3.2.1
Site details - location, geology, crop and climate

CODE	FC DISTRICT/ ESTATE	FOREST / WOOD	CPT/ PSP	NO.	GRID REF.	GEOLOGY PERIOD	GEOLOGY TYPE	CROP	P-YEAR	CLIMATE
ABF 1	FC ABERFOYLE	TENTSMUIR	*CPT*	*8310*	NO 493279	LITTORAL	SAND	SP	1933	WD
ABF 2	FC ABERFOYLE	LOCH ARD	PSP	3266	NN 489012	DALRADIAN	MICA SCHIST	JL	1930	CW
AE 1	FC AE	AE	*CPT*	*131*	NX 983915	SILURIAN	GREYWACKE	NS	1949	CW
AE 2	FC AE	MABIE	*CPT*	*6168a*	NX 935705	SILURIAN	SHALE	NS	1951	CM
AWE 1	FC LOCH AWE	KILMICHAEL	*CPT*			DALRADIAN	MICA SCHIST	SS		CW
BAL 1	BALMORAL ESTATE	GARMADDIE	PSP	3029	NO 216924	INTRUSIVE	GRANITE	SP	1886	CM
BCH 1	FC BUCHAN	CLASHINDARROCH	*CPT*	*3318*	NJ 488317	DALRADIAN	MICA SCHIST	GF/ NS	1936	CM
BCH 2	FC BUCHAN	LESCHANGIE	PSP	3080	NJ 740156	INTRUSIVE	GRANITE	EL	1930	CM
CER 1	FC CEREDIGION	CWM YSTWYTH	PSP	2058	SN 715705	SILURIAN	SHALE	JL	1933	WW
CHT 1	FC CHILTERNS	QUEEN & COLLEGE	PSP	1373	SU 723923	CRETACEOUS	CHALK	BE	1814	WD
DEN 1	FC DEAN/ 3 COUNTIES	DEAN	PSP	1097	SO 544113	DEVONIAN	SANDSTONE	OK	1910	WM
DEN 2	FC DEAN/ 3 COUNTIES	DEAN	PSP	1414	SO 628060	CARBONIF.	SANDSTONE	EL	1934	WM
DEN 3	FC DEAN/ 3 COUNTIES	DEAN	PSP	1413	SO 662122	DEVONIAN	SANDSTONE	OK	1928	WD
DEN 4	FC DEAN/ 3 COUNTIES	DEAN	PSP	1419	SO 539113	DEVONIAN	SANDSTONE	SYC/EL	1932	WM
DEN 5	FC DEAN/ 3 COUNTIES	DYMOCK	PSP	1030	SO 688288	DEVONIAN	SANDSTONE	OK	1862	WD
DEN 6	FC DEAN/ 3 COUNTIES	DEAN	*CPT*	*448g*	SO 668119	DEVONIAN	SANDSTONE	OK	1930	WD
DEN 7	FC DEAN/ 3 COUNTIES	KINGS WOOD WARR.	PSP	1226	ST 744355	CRETACEOUS	GREENSAND	JL	1934	WD
DST 1	FC DORSET	BLANDFORD	PSP	1405*	ST 826083	CRETACEOUS	CHALK	OK	1910	WD
DOW 1	FC DOWNS	ALICE HOLT	PSP	1429	SU 814425	CRETACEOUS	GAULT CLAY	SP	1937	WD
DOW 2	FC DOWNS	MICHELDEVER	PSP	1321	SU 533376	CRETACEOUS	CHALK	OK	1928	WD
DOW 3	FC DOWNS	BRAMSHILL	PSP	1433	SU 748621	TERTIARY	BAG. SAND	SP	1923	WD
DOW 4	FC DOWNS	LIPHOOK	PSP	1743	SU 835293	CRETACEOUS	GREENSAND	SP	1960	WD
DOW 5	FC DOWNS	BLACK WOOD	PSP	1255	SU 537415	CRETACEOUS	CHALK	SYC/ AH	1925	WD
DOW 6	FC DOWNS	HURSLEY	PSP	1325	SU 432238	CRETACEOUS	LOND. CLAY	OK	1913	WD

Figure 3.2.1
Site details - location, geology, crop and climate

CODE	FC DISTRICT/ ESTATE	FOREST / WOOD	CPT/ PSP	NO.	GRID REF.	GEOLOGY PERIOD	GEOLOGY TYPE	CROP	P-YEAR	CLIMATE
GTN 1	GLEN TANAR ESTATE	DINNET OAKWOOD	SEMI	NAT	NO 463981	DALRADIAN	LIMESTONE	OK/ BI	SEMINAT	CM
INV 1	FC INVERNESS	CULBOKIE	PSP	3245	NH 613589	DEVONIAN	SANDSTONE	SP	1929	WD
INV 2	FC INVERNESS	CULLODEN	PSP	3080	NH 721487	DEVONIAN	SANDSTONE	DF	1905	WD
KCD 1	FC KINCARDINE	DRUMTOCHTY	PSP	3282	NO 682768	DEVONIAN	SANDSTONE	JL	1935	CM
KCD 2	FC KINCARDINE	DRUMTOCHTY	PSP	3170	NO 694796	DEVONIAN	SANDSTONE	HL	1928	CM
KIN 1	FC KINTYRE	KNAPDALE	*CPT*			DALRADIAN	MICA SCHIST	SS		CW
KIN 2	FC KINTYRE	KNAPDALE	*CPT*			DALRADIAN	MICA SCHIST	SS		CW
LAK 1	FC LAKES	THORNTHWAITE	*CPT*	*2044b*	NY 217246	ORDOVICIAN	SHALE	JL	1953	CW
LAK 2	FC LAKES	GRIZEDALE	*CPT*	*739a*	SD 333930	SILURIAN	SHALE	OK	1898	WW
LAK 3	FC LAKES	DODD	PSP	1264	NY 238280	ORDOVICIAN	SHALE	DF	1930	WW
LCH 1	FC LOCHABER	LEANACHAN	*CPT*	*3001f*	NN 148762	INTRUSIVE	GRANITE	JL	1932	CW
LND 1	FC LLANDOVERY	PEMBREY	PSP	2156	SN 386035	LITTORAL	SAND	CP	1931	WM
LND 2	FC LLANDOVERY	PEMBREY	PSP	2154	SN 403013	LITTORAL	SAND	CP	1932	WM
LWT 1	FC LLANRWST	GWYDR	PSP	2170	SH 785578	ORDOVICIAN	RHYOL. TUFF	SP	1924	CW
LWT 2	FC LLANRWST	GWYDR	PSP	2194	SH 762572	ORDOVICIAN	SHALE	SS	1940	WW
LOT 1	FC LOTHIAN & TWEED	GLENTRESS	PSP	3142	NT 282415	SILURIAN	GREYWACKE	NS	1902	CM
LOT 2	FC LOTHIAN & TWEED	GLENTRESS	PSP	3158	NT 286417	SILURIAN	GREYWACKE	JL	1926	CM
MCH 1	FC MARCHES	WYRE	PSP	1271	SO 737763	CARBONIF.	SANDSTONE	OK	1888	WD
MCH 2	FC MARCHES	WIGMORE ROLLS	*CPT*	*?*	SO 396693	SILURIAN	SHALE	AH/EL	?	WM
MID 1	FC MIDLANDS	CANNOCK	PSP	1331	SK 018158	TRIASSIC	SANDSTONE	SP	1925	WD
MOR 1	FC MORAY	MONAUGHTY	PSP	3185	NJ 157585	DEVONIAN	SANDSTONE	GF	1928	WD
MOR 2	FC MORAY	CULBIN	PSP	3114*	NJ 022628	LITTORAL	SAND	SP	1878	WD
MOR 3	FC MORAY	TEINDLAND	*CPT*	*3036e*	NJ 283541	DEVONIAN	SANDSTONE	SS/LP	1948	CM

Figure 3.2.1
Site details - location, geology, crop and climate

CODE	FC DISTRICT/ ESTATE	FOREST / WOOD	CPT/ PSP	NO.	GRID REF.	GEOLOGY PERIOD	GEOLOGY TYPE	CROP	P-YEAR	CLIMATE
NEW 1	FC NEW	NEW	PSP	1312	SU 227055	TERTIARY	BART. SAND	SP	1926	WD
NTH 1	FC NORTHANTS	FINESHADE	PSP	1344*	SP 942969	JURASSIC	LIMESTONE	OK	1929	WD
NTH 2	FC NORTHANTS	APETHORPE	PSP	1345*	SP 999940	JURASSIC	LIMESTONE	NS	1929	WD
NYM 1	FC NORTH YORK MOORS	DALBY	*CPT*	*4238c*	SE 857860	JURASSIC	SANDSTONE	SS	1926	WM
SEA 1	SEAFIELD ESTATE	CURR	PSP	3068*	NH 987226	MOINE	SCHIST	SP	1881	CM
SEW 1	FC SOUTH EAST WALES	CWMCARN	PSP	2094	ST 258954	CARBONIF.	SANDSTONE	SP	1935	WW
SFD 1	STOCKSFIELD ESTATE	STOCKSFIELD	PSP	1224	NZ 043602	CARBONIF.	SANDSTONE	CP	1873	CM
SNT 1	LOCH SUNART NNR	ARIUNDLE OAKWOOD	SEMI	NAT	NM 832637	INTRUSIVE	GRANITE	OK/BI	SEMINAT	CW
SWD 1	FC SHERWOOD	WHITWELL	PSP	1367	SK 520788	PERMIAN	LIMESTONE	SYC	1939	WD
SWD 2	FC SHERWOOD	SHERWOOD	PSP	1601	SK 592530	TRIASSIC	SANDSTONE	CP	1945	WD
SWD 3	FC SHERWOOD	SHERWOOD	PSP	1368	SK 599755	TRIASSIC	SANDSTONE	JL	1929	WD
SWP 1	FC SW. ENGL. PENIN.	WELL, LISKEARD	PSP	1192	SX 155664	DEVONIAN	SHALE	SS	1927	WM
SWP 2	FC SW. ENGL. PENIN.	ABBEYFORD	PSP	1215	SX 588982	CARBONIF.	CULM SHALE	JL	1931	WW
SWP 3	FC SW. ENGL. PENIN.	BRENDON	PSP	1393	SS 948440	DEVONIAN	SANDSTONE	JL	1934	WD
TAY 1	FC TAY	DRUMMOND HILL	PSP	3238	NN 736448	DALRADIAN	MICA SCHIST	JL	1926	CM
TAY 2	FC TAY	KINFAUNS	PSP	3293	NO 157224	DEVONIAN	ANDESITE	SYC/AH	1929	WM
THT 1	FC THETFORD	THETFORD	PSP	1755	TL 807767	CRETACEOUS	CHALK	SP	1964	WD
THT 2	FC THETFORD	THETFORD	PSP	1131	TL 771851	CRETACEOUS	CHALK	SP	1906	WD
THT 3	FC THETFORD	THETFORD	PSP	1436	TL 943857	CRETACEOUS	CHALK	OK	1934	WD
THT 4	FC THETFORD	THETFORD	PSP	1134	TF 807057	CRETACEOUS	CHALK	SP	1922	WD
THT 5	FC THETFORD	THETFORD	PSP	1179	TL 793929	CRETACEOUS	CHALK	CP	1903	WD
THT 6	FC THETFORD	THETFORD	PSP	1308	TL 814976	CRETACEOUS	CHALK	OK	1928	WD
WLD 1	FC WEALD	BEDGEBURY	PSP	1580	TQ 724337	JURASSIC	HAST. SAND	PP	1960	WD

Figure 3.3.1 Site: SEA1 - Seafield Estate, Speyside
Crop: *Pinus sylvestris* Geology: Moine schist

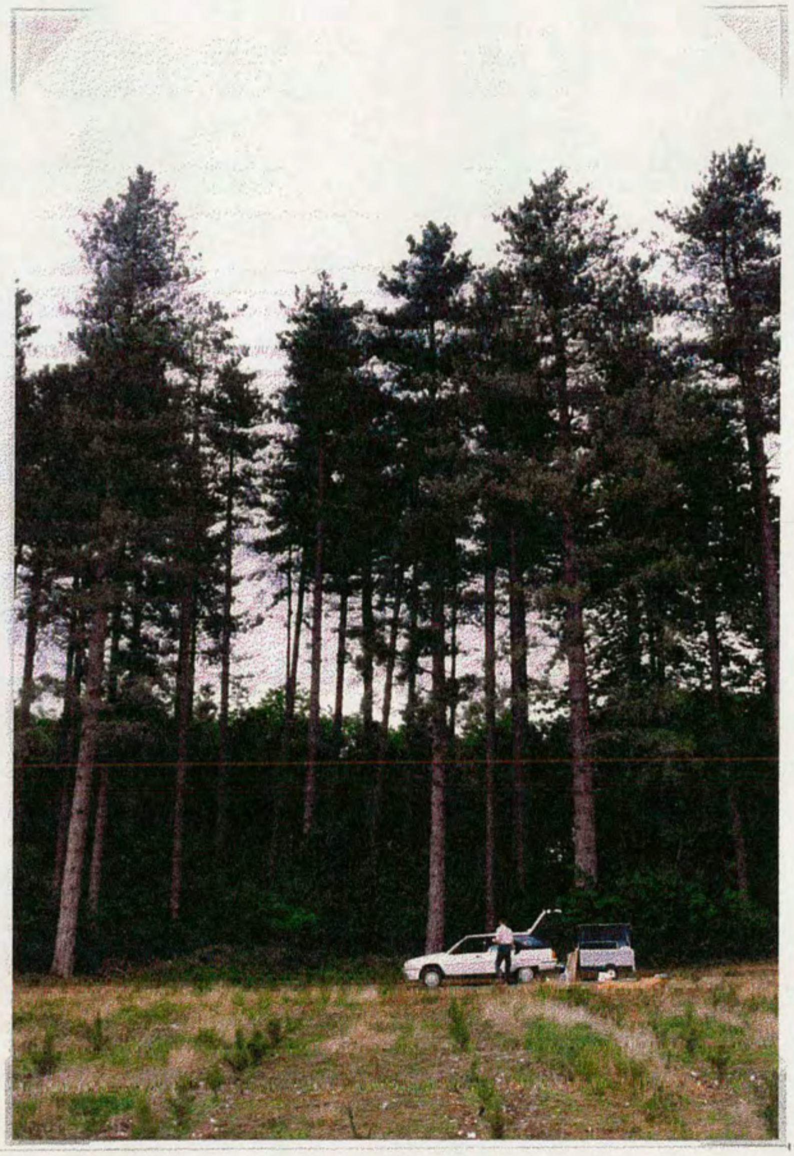


Figure 3.3.2 **Site: THT5 - Thetford Forest**
Crop: *Pinus nigra* **Geology: Sand over Cretaceous chalk**

Figure 3.3.3 **Site: KCD1 - Drumtochty Forest, Kincardine**
Crop: *Larix kaempferi* **Geology: Devonian sandstone**

Figure 3.3.4 **Site: LOT1 - Glentress Forest, Peebleshire**
Crop: ***Picea abies*** **Geology: Silurian greywacke**

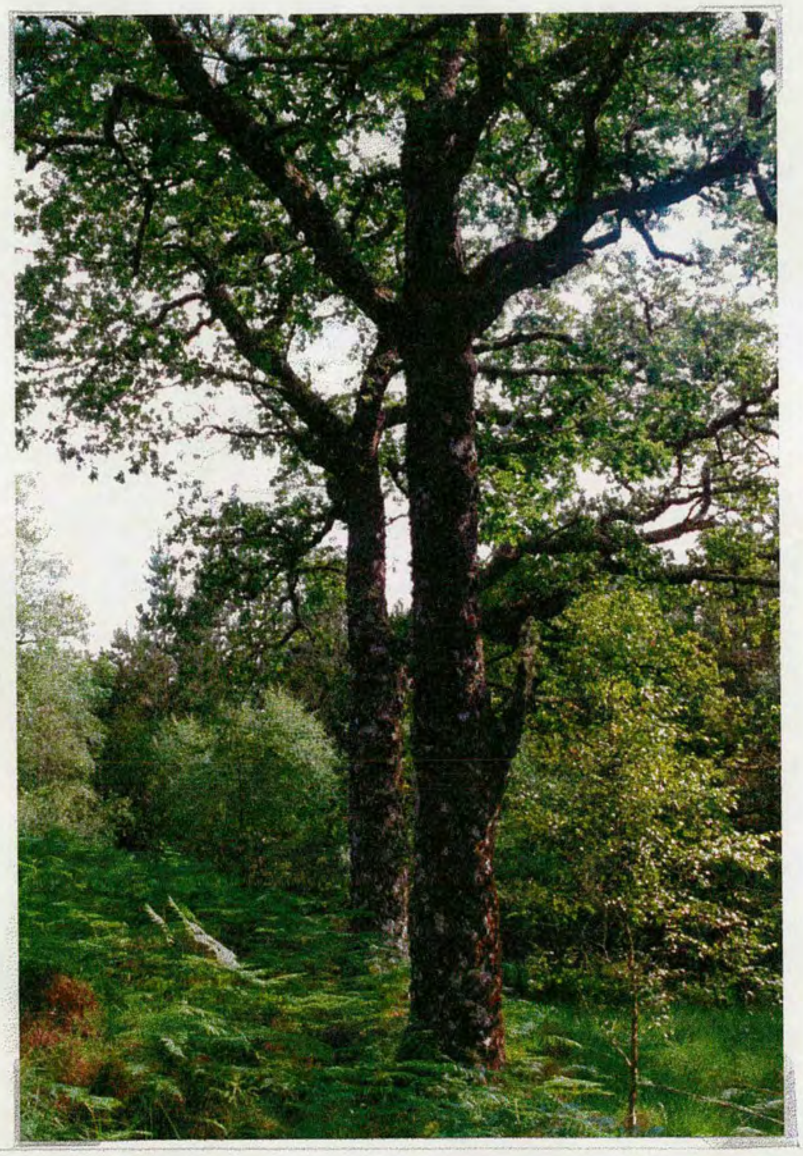


Figure 3.3.5 **Site: SNT1 - Ariundle oakwood, Loch Sunart**
Stand: ***Semi-natural oak-birch woodland*** **Geology: Granite**

Figure 3.3.6 **Site: DOW2 - Micheldever Forest, Hampshire**
Crop: *Quercus spp.* **Geology: Clay over Cretaceous chalk**

Figure 3.3.7 **Site: SWD1 - Whitwell Wood, Derbyshire**
Crop: *Acer pseudoplatanus* **Geology: Permian magn. limestone**

3.4 Historical information regarding sites sampled

The history of land-use and vegetation on a forest site has been shown to be a significant factor in the development of its present soil condition and vegetation species composition. Rackham (pers. comm.) and Peterken (1993) have considered the possibility that certain species can act as "ancient woodland indicators" in British woodlands, especially those in the lowlands. Rackham (pers. comm.) has also suggested that the past practice of coppicing in many broadleaved woodlands has favoured a group of opportunistic species known as "coppicing plants". Ovington (1953, 1954, 1955, 1956a,b, 1958a,b) examined in detail the effect which different woodland types have on both the ground vegetation under the woodland and on the development of soil and humus nutrient properties. Dimbleby (1962) examined the development of podzolic conditions in British heathland soils [many now afforested], and the mitigating effects that the establishment of certain broadleaved tree species could have upon these soils. Much work in North American forests has also considered the influence of site history.

Fortuitously, for those of the 70 plots sampled within this study which are F.C. Permanent Sample Plots, it is possible, in many cases, to get some idea of the site history prior to the establishment of the current crop. This information is recorded on the forms completed at adoption of the stand as a measurement plot. These sites fall into four main categories:-

(A) those which have a long history of woodland cover, with the current stand resulting from re-stocking

(B) those which were established on some form of waste ground which may have had partial tree cover, and often *Pteridium aquilinum* [(L.) Kuhn]

(C) those which were established on former heathland or moorland which was largely treeless, with *Calluna vulgaris* [(L.) Hull], *Vaccinium spp.* [L.], *Deschampsia flexuosa* [(L.) Trin.] or *Molinia caerulea* [(L.) Moench]. This would normally have been used for grazing for a long period.

(D) those which were established on recently tilled arable land.

Summary site histories for the 70 plots are presented in Figure 3.4.1.

Figure 3.4.1

Summary of site historical information

PLOT CODE	LAND TYPE	SITE HISTORICAL INFORMATION
ABF 1	D	Much of Tentsmuir cultivated until early C20th
ABF 2	C	Stated to be rough upland grazing land
AE 1	A	Assumed former streamside woodland
AE 2	A	Assumed former streamside woodland
AWE 1	C	Assumed heather moorland
BAL 1	A or C	Stated to be a flood-prone gravel terrace Prior failed stocking with larch in 1870's
BCH 1	A	Assumed former streamside woodland
BCH 2	B	Assumed former scrub woodland Surrounding bracken cover on quarry waste
CER 1	C	Stated to be heather moorland Heather, bracken, gorse cover
CHT 1	A	Thought to be semi-natural beechwood site
DEN 1	A	Mention of previous stocking of site with oak
DEN 2	A or B	Assumed oak woodland/ scrub woodland
DEN 3	A or B	Assumed oak woodland/ scrub woodland
DEN 4	A	Stated to be former mature coppice oakwood Understorey of ash, birch, beech & hazel Stand was sycamore trial with larch matrix
DEN 5	A	Oak coppice with standards Last coppiced ~1880/ conversion to high-forest
DEN 6	A or B	Assumed oak woodland/ scrub woodland Stand probably established as oak trial
DEN 7	A or B	Assumed oak woodland/ scrub woodland
DST 1	D	Inclusion from arable land adjoining
DOW 1	A	Stated to be former oak high-forest Unmanaged sweet chestnut understorey
DOW 2	A	Assumed continuous oak woodland cover
DOW 3	B or C	Assumed scrub woodland or heathland Stated to have burned over circa 1920.
DOW 4	A or B	Stated to be old woodland/ bracken cover
DOW 5	A	Stated to have been oak wood with hazel Colonised by ash/ sycamore regeneration
DOW 6	A or D	Probably oak woodland Potentially an inclusion of arable land
GTN 1	A	Known to be an ancient woodland

Figure 3.4.1
Summary of site historical information

PLOT CODE	LAND TYPE	SITE HISTORICAL INFORMATION
INV 1	D	Stated to be former arable crofting land Plough pan at shallow depth noted previously
INV 2	A or B	Assumed woodland or scrub woodland Stand originally a mixture of larch/ Douglas fir
KCD 1	C	Stated to have been heather moorland
KCD 2	C	Assumed to have been heather moorland
KIN 1	C	Assumed heather moorland/ upland grazing land
KIN 2	C	Assumed heather moorland/ upland grazing land
LAK 1	B or C	Assumed scrub woodland/ upland grazing land
LAK 2	A or B	Assumed woodland/ scrub woodland
LAK 3	A or B	Assumed gorge woodland due to steepness
LCH 1	C	Assumed moorland/ upland grazing land
LND 1	B	Stated to be vegetated mobile dune
LND 2	B	Stated to be bed of former "dune winter lake"
LOT 1	A or B	Pre-Forestry Commission conifer plantation Assumed formerly grazing land/ woodland
LOT 2	B or C	Assumed former upland grazing land
LWT 1	B or C	Rocky outcrop - possibility of topsoil addition Part of former upland sheep small-holding
LWT 2	B or C	Assumed former upland grazing land
MCH 1	A	Known to be old coppice oak woodland
MCH 2	A	Assumed to be ancient woodland site
MID 1	B	Known to be waste ground around coalmines
MOR 1	B	Stated to be bracken covered with some trees
MOR 2	B	Known to be afforested sand dunes
MOR 3	C	Known to have been heather moorland
NEW 1	A	Assumed to be an oak woodland site Pine was planted as nurse to oak, now dead
NTH 1	A	Assumed woodland (known as "Wood Hollow")
NTH 2	D	Stated to have been former arable land
NYM 1	A	Assumed streamside woodland

Figure 3.4.1
Summary of site historical information

PLOT CODE	LAND TYPE	SITE HISTORICAL INFORMATION
SEA 1	A or C	Assumed to be a native pinewood/ heather site Stand arose from uniform shelterwood regen.
SEW 1	C	Stated to have been moorland (peaty topsoil) Cover assumed to have been heather or *Molinia*
SFD 1	A or B	Assumed woodland/ scrub woodland
SNT 1	A	Known to be an ancient woodland
SWD 1	A	Known to be an ancient woodland
SWD 2	A or B	Assumed woodland or scrub woodland Site burned over in 1940's
SWD 3	B	Stated to be a heath with sweet chestnut stools
SWP 1	D	Stated to be an arable clearing in oak woodland
SWP 2	B	Assumed to be a heath with woodland scrub
SWP 3	C	Stated to be heath with heather, bracken, grass Stand was part of a thinning trial (Zehetmayr)
TAY 1	C	Assumed upland grazing land Stand part of a larch provenance trial
TAY 2	A	Likely to have had woodland cover Stand arose by natural regen. after 1927 blow
THT 1	B or C	Assumed scrub woodland/ heathland
THT 2	B or C	Probably heath with heather and birch trees Possibility of a prior pine stand
THT 3	D	Stated to be former arable land Stand arose from oak-pine mix (direct sown?)
THT 4	B or C	Assumed scrub woodland/ heathland
THT 5	B or C	Assumed scrub woodland/ heathland Former use for coppice sweet chestnut stools Stand arose from oak-pine mix
THT 6	B or C	Assumed scrub woodland/ heathland
WLD 1	B or C	Stated to be heathland Heather, bracken and birch cover

4. SOIL SAMPLING - METHODOLOGY AND FIELD RESULTS

4.1 Literature review of soil survey and sampling methodology

The literature will be reviewed in three groups:- relating to (a) the survey of soil type, (b) the survey of soil nutrient properties and (c) the survey of humus type and chemical properties.

Soil type

The majority of conventional soil survey has recorded soil-type and in some cases a description of the profile according to a standard scheme. The purpose of the survey is normally to underpin agricultural advice. Avery (1990) provides an up-to-date account of the standard mode of profile description employed in this country. A numerical approach can also be used to describe soil profiles [Howard & Howard (1987)] A complete survey of Great Britain at the 1:250,000 scale was completed some years ago by the Soil Surveys of England and Wales and of Scotland. For their field methodology see Hodgson (1974) and Soil Survey of Scotland (1984). A number of local areas have also been surveyed in more detail by the same methods. In addition to the above mentioned descriptors of soil-type these surveys usually refer to "soil series" which are named after the place where that particular soil was first identified. Hence within the major categories such as "brown earth", there are a number of "series" referring mainly to local parent materials. At an international level a different system of classification is used as a common reference point [F.A.O. scheme]. This adopted the terminology of the United States Soil Survey, which uses a system of main groups [e.g. "cambisol"], qualified by descriptors [e.g. "dystric"]. This system has not been widely adopted in Great Britain for domestic use.

Effective survey of soil-type for use in forest management and forest site classification requires a much higher resolution than the 1:250,000 scale provides. The Forestry Commission has undertaken the soil survey of many of its forests at a scale of

1:10,000 or greater. There was a period of concentrated survey activity in the 1960's and 1970's [Pyatt, pers. comm.], during which certain major forests [e.g. North York Moors, New Forest, Coed Morgannwg] were soil-mapped. However this intensive work came to an end before all the forests had been covered [e.g. the Forest of Dean is unmapped], and the rate of extension is now very slow due to resource limitations. Forest soil survey taking place today is mainly on a "site-by-site" basis such as the work for this project. The Forestry Commission employs a system of soil-type classification similar to that of the national Soil Survey, but with some minor modifications to suit forest conditions [Pyatt (1970, 1982)]. Other European countries have their own systems of forest soil-type classification, although many are now tending to adopt the F.A.O. system. Of particular note are the Scandinavian systems for classifying peat types [Heikurainen (1972, 1979)].

Soil nutrient properties

Little extensive field survey of forest soil nutrient regime has been undertaken in Great Britain to date. This is true of most countries, although the extent of work carried out in parts of Germany [e.g. the Black Forest], perhaps come closest to it. Certain woods and forests in Great Britain have had maps produced of soil pH only, but these cover a very small fraction of the total forest area. Examples include Thetford [Forestry Commission] and Bradfield Wood, Suffolk [Rackham, pers. comm.] The amount of work involved in mapping multi-parameter soil nutrient regime has been regarded as too great to cover extensive areas. From this stems the interest in using ground vegetation and humus type as surrogates of soil nutrient regime, which can be mapped much more easily.

A great number of research projects have, however, carried out sampling programmes of various soil nutrient variables at selected sites, either in forests or where forest establishment is under-way. Malcolm (1970) measured a number of nutrient variables in his study of the site-yield relations of *Picea sitchensis* in four Scottish plantation forests, and much work of this kind has been aimed at prediction of yield or diagnosis of specific nutrient deficiency in plantation forests [Khanna & Ulrich (1984)]. Many studies have been aimed at investigating the relationship between vegetation and soil nutrient regime. Muir & Fraser (1939) at Bin and Clashindarroch forests in Aberdeenshire measured several nutrient parameters and attempted to relate them to the pre-establishment ground vegetation. Ovington (1953, 1956a, 1958a,b) carried out a comprehensive programme, for its time, in an attempt to study the development of soil nutrient conditions under a variety of types of woodland cover in Great Britain. Page (1968, 1974) examined the impact of coniferous forest cover on soil nutrient regime in Newfoundland forests. More recent work has usually been aimed at investigating nutrient [particularly nitrogen] cycling in forest soils [Mahendrappa *et al* (1986)] or at producing a classification of forest soil nutrient regime [Hawkes, Pyatt & White (1997), Howard and Howard (1987), Kabzems & Klinka (1987)].

The methodology of soil sampling for nutrient analysis must be planned, taking into account the following issues:- (a) sampling depth, (b) replication to account for point-to-point and temporal variation, (c) means of abstracting the sample and (d) means of determining bulk density [if nutrients are to be reported on a volume or spatial basis, as opposed to only as mass fractions]. These matters are considered generally by Gjems *et al* (1960) and Mroz & Reed (1991). Variability is examined by Godbout & Brown (1995). A method for determining bulk-density of stony soils in the laboratory has been put forward by Tamminen & Starr (1994).

There is considerable debate in the literature concerning the appropriate depth to which to sample for maximal effectiveness in nutrient diagnosis. Those workers approaching the issue from a nutrient-cycling perspective tend to suggest that an examination of the upper horizons [O and A/Ah] yields the majority of useful information, which might imply a sampling depth of 10-20cm. Certain Continental workers on the other hand, taking a more pedological perspective, extend their sampling, in some cases, to beyond 1 m on the basis that this still lies within the rooting zone of many trees. In Great Britain, a sampling depth of 50-70 cm has been considered to include a majority of the root-available nutrients for most soils, and is considerably more appropriate as a sampling depth in many soils than would be 1 m or more.

There has been a general movement away from single point sampling from the face of a soil pit towards the use of multi-point techniques such as core and "post-hole" sampling. This has been in response to the increasing appreciation of the point-to-point variability in forest soil nutrient properties. An upper-limit is usually set on the number of sample points by logistical considerations rather than by a statistically derived level. If the sampling can be conducted by a volumetric means such as coring, the need for a subsequent determination of bulk density is removed. This may lead to an improvement in the accuracy of volume or spatial expressions of soil nutrient availability.

Humus type and chemical properties

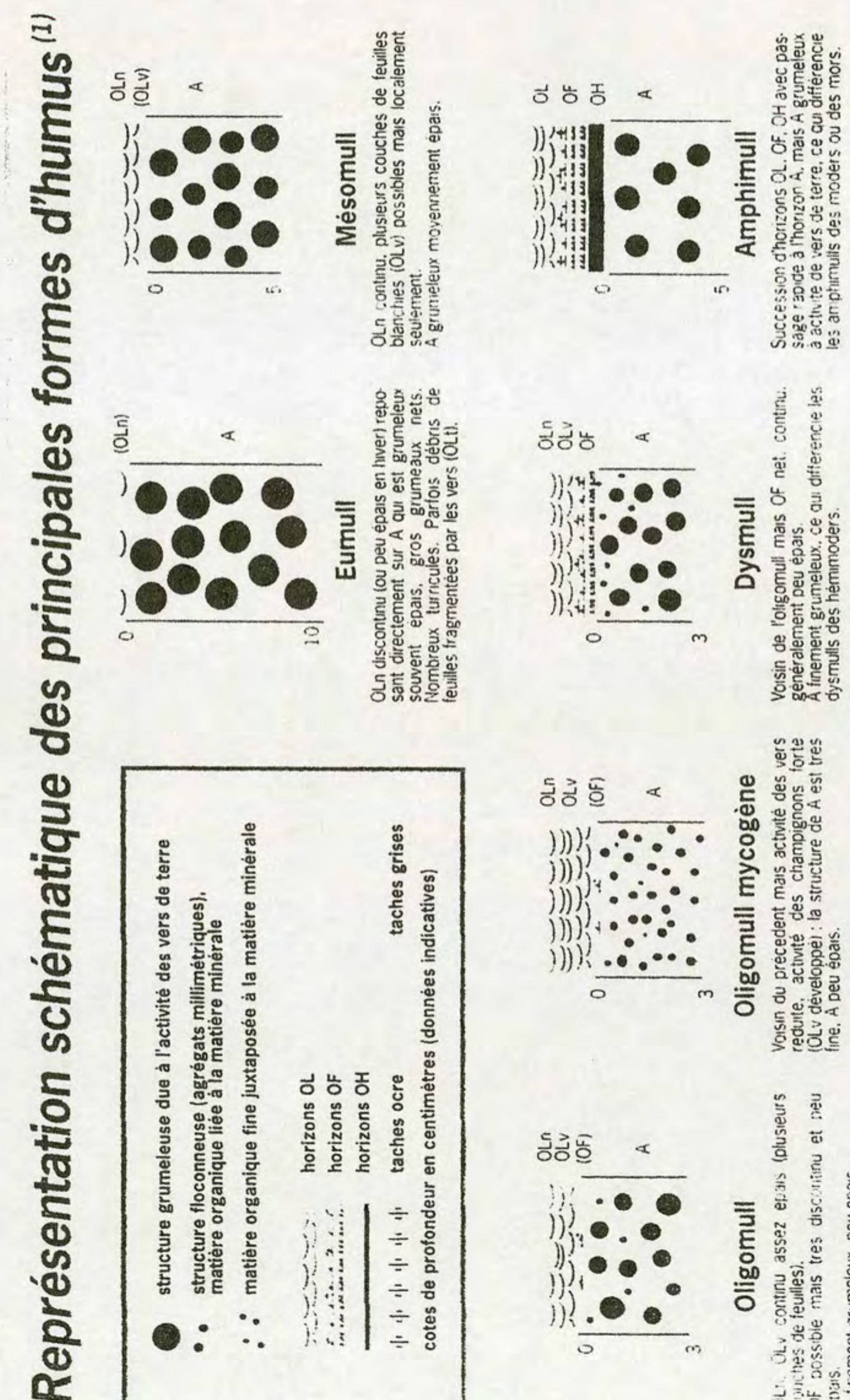
The study of forest humus type has been pursued in both Continental Europe and North America, but not to such a degree in Great Britain. This perhaps is due to the fact that humus [also sometimes known as "forest floor"] does not build up until a forest reaches a certain stage of maturity, and indeed takes considerably longer to achieve an equilibrium condition. The majority of British plantation forests are only now reaching an age where this is of interest. However three early examinations of the subject are to be recommended:- *"The ecology of the humus layer in some English forests"* [Puri (1950)], that part of Ovington's *"Studies of the development of woodland conditions under different trees"* entitled *"II. The forest floor "* [Ovington (1954)] and, finally, Handley's (1954) FC Bulletin *"Mull and mor formation in relation to forest soils"*. Dimbleby (1962), although mainly considering humus as an adverse product of ericaceous heathland vegetation conditions, did examine the impact of different tree species upon its subsequent development. More recent work has tended to move on from humus morphology to its organic chemistry and nutrient turnover [Howard & Howard (1990)]. Certain coniferous species, especially when grown in single-species even-aged plantations are suggested to give rise to infertile mor forms that lock up nutrients [notably *Tsuga heterophylla* [(Raf.) Sarg.] but also *Picea abies* [(L.) Karsten], *Pinus spp.* [L.] and possibly *Picea sitchensis* under certain conditions]. Others conifers such as *Abies spp.* [Miller] and *Thuja plicata* [Donn ex D. Don], together with most broadleaves [notably *Betula spp.* [L.] [Gardiner (1968), Nykvist (1961)] but not including *Fagus sylvatica* [L.]] are suggested to be "site improvers" [Troedsson (1983)].

In France and Belgium the study of humus, and its classification, has developed from the work of Manil (1958) and Duchaufour (1962), into what is now a sophisticated analysis [Brethes *et al* (1992), Jabiol *et al* (1995)]. The original three main categories of mull, moder and mor are retained but the former two categories are each subdivided morphologically [see Figure 4.1.1]. The weighting towards the mull end of the range reflects the predominance of more fertile soil nutrient conditions in France. The structure of the humus is described in terms of an uppermost "L" layer (litter), central "F" layer (fermentation) and basal "H" layer (humification). Not all are present in every humus type. The classification is based on features such as layer presence, layer thickness (absolute and relative), texture and cohesion and the abruptness or otherwise of delineation of the humus from the mineral soil.

In North America the development of humus classification has reached a similar stage of sophistication, particularly in British Columbia. Much of the literature reflects the work of Karel Klinka. [Green, Trowbridge & Klinka (1993), Lowe & Klinka (1981), Klinka *et al* (1981, 1995), Klinka, Wang & Carter (1990) and Qian & Klinka (1995)]. The humus classification used within the B.E.C. site classification regime is of similar complexity to the French, but tends to be weighted towards the mor end of the range to suit local conditions [see Figure 4.1.2]. Wilde (1966) produced a *"a new terminology for forest humus layers"* in the United States.

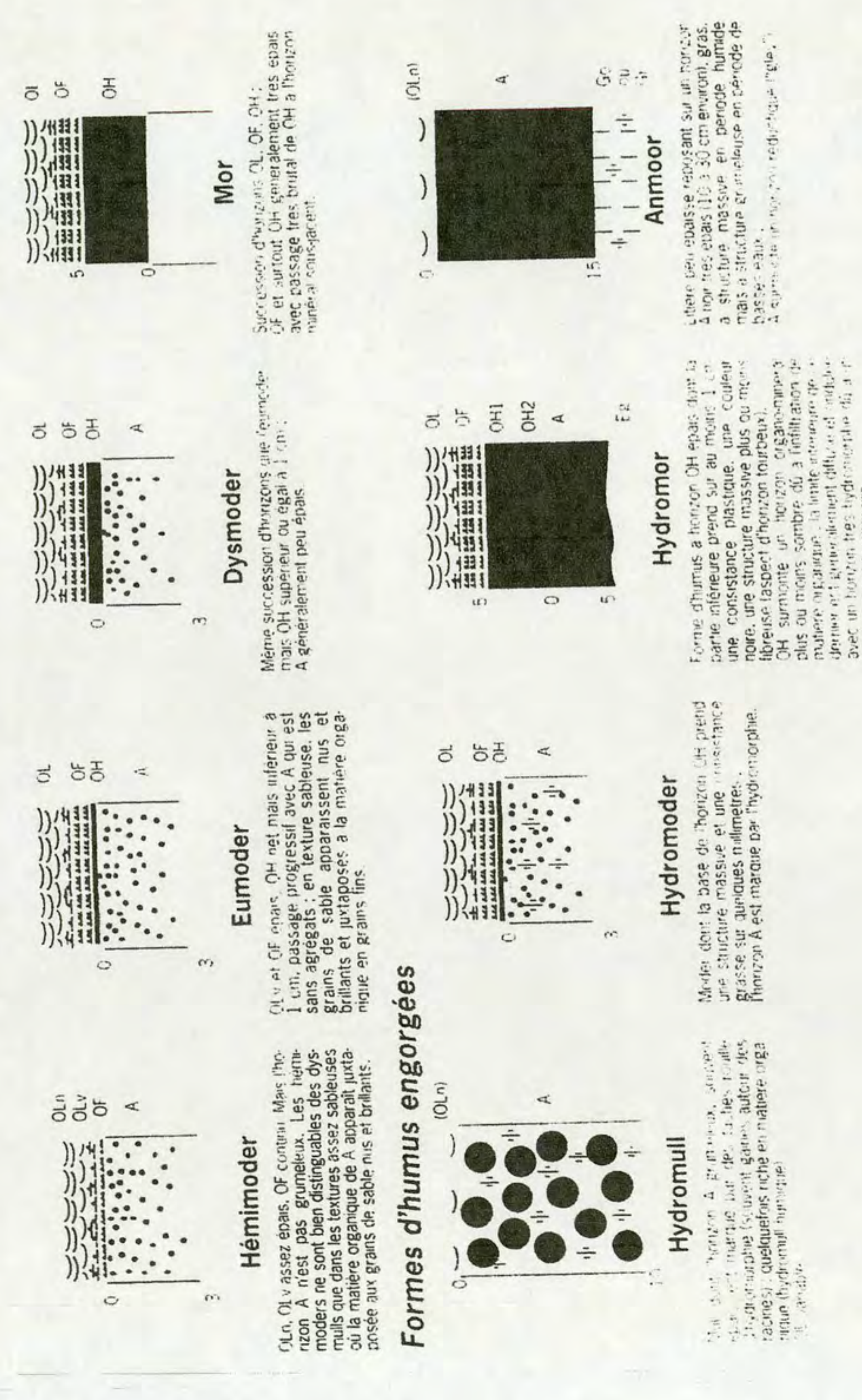
Some workers have begun to examine the potentially vast subject of humus microbiology [Mardulyn *et al* (1992),Moore *et al* (1994)]

Figure 4.1.1 Schematic representation of the French humus form taxonomy



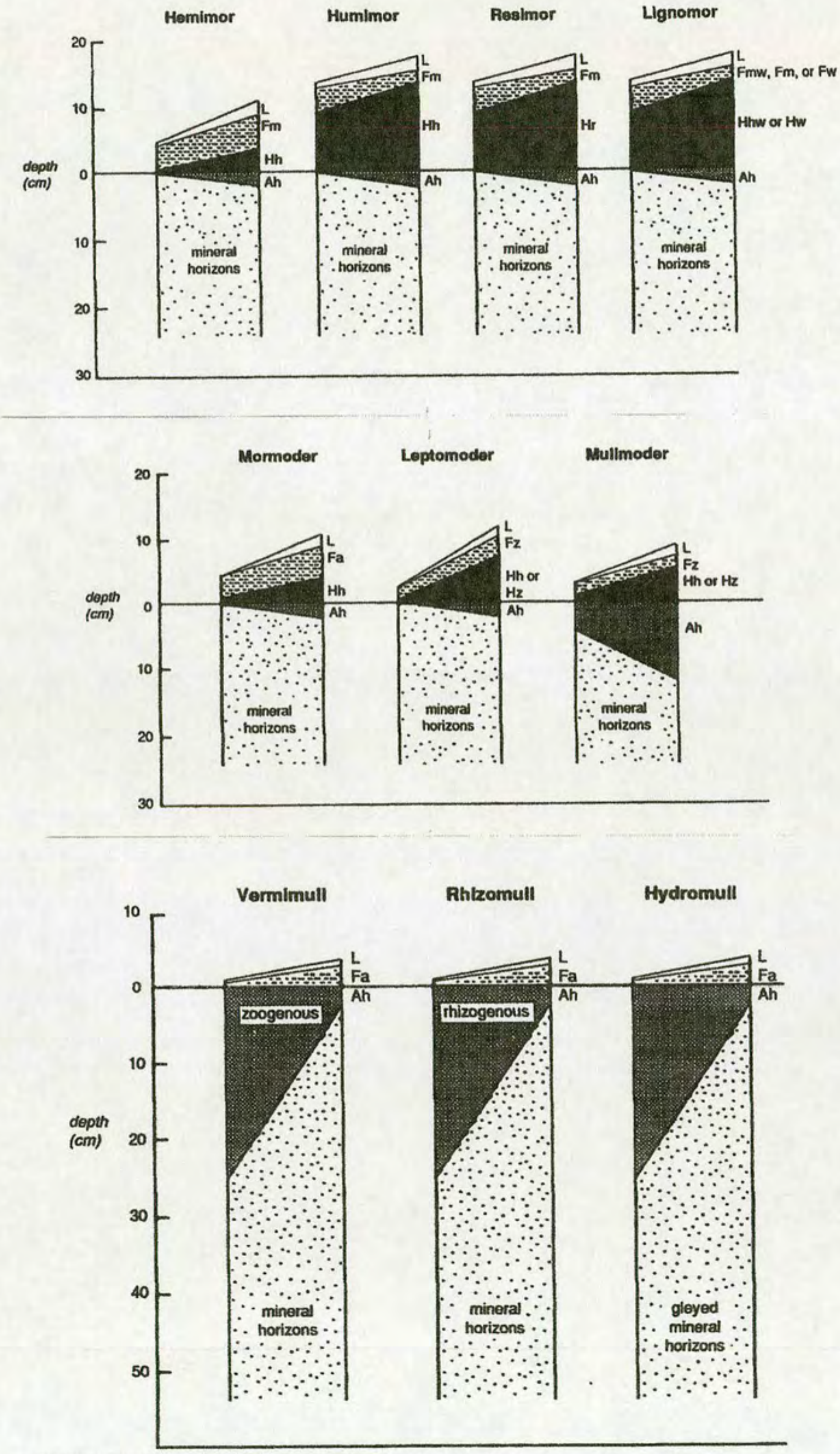
Taken from: **Jabiol *et al* (1995)**

Figure 4.1.1 Schematic representation of the French humus form taxonomy



Taken from: **Jabiol *et al* (1995)**

Figure 4.1.1 Schematic representation of the B.C. humus form taxonomy



Taken from: **Green, Trowbridge & Klinka (1993)**

Figure 4.1.1 Key to the British Columbian humus form taxonomy

Key to Humus Forms

1a. Well to imperfectly drained sites; humus form not saturated for prolonged periods
  - 2a. Combined thickness of F and H horizons > 2 cm; or ⩽ 2 cm if Ah < 2 cm
    - 3a. F horizon(s) is Fm **MORS**
      - 4a. Decaying wood >35% of organic matter volume in humus form profile **Lignomor**
      - 4b. Decaying wood ⩽35% of organic matter volume in humus form profile
        - 5a. F horizon >50% of thickness of F and H horizons **Hemimor**
        - 5b. Hh horizon >50% of thickness of F and H horizons **Humimor**
        - 5c. Hr horizon >50% of thickness of F and H horizons **Resimor**
    - 3b. F horizon(s) includes Fz and/or Fa **MODERS**
      - 4a. Decaying wood >35% of organic matter volume in humus form profile **Lignomoder**
      - 4b. Decaying wood ⩽35% of organic matter volume in humus form profile
        - 5a. Fa horizon >50% of thickness of F horizons; or Fm horizon present **Mormoder**
        - 5b. Fz horizon >50% of thickness of F horizons
          - 6a. F and H horizons ⩾ thickness of Ah horizon **Leptomoder**
          - 6b. F and H horizons < thickness of Ah horizon **Mullmoder**
  - 2b. Combined thickness of F and H horizons ⩽ 2 cm with Ah horizon > 2cm **MULLS**
    - 3a. Rhizogenous Ah horizon formed from decomposition of dense fine roots **Rhizomull**
    - 3b. Zoogenous Ah horizon formed through actions of abundant earth-worms **Vermimull**

Taken from: **Green, Trowbridge & Klinka (1993)**

4.2 Description of soil sampling methods

At each site a conventional soil pit was excavated, usually to 60-70cm depth, roughly in the centre of the area to be studied. The soil type was determined according to the Forestry Commission scheme [Pyatt (1982)], and the humus type according to the British Columbian scheme [Green, Trowbridge & Klinka (1993)]. [In addition, the detailed descriptions made were later used to assign the humus types to the French scheme classes [Jabiol *et al* (1995)]] The soil and humus profiles were then described on a standard horizon basis [Avery (1990)], citing colour [using a Munsell (1988) colour key], texture, structure, consistency, stoniness [by visual volume estimate], presence and abundance of rooting and any other special features. The profile was photographed using ISO 400 colour film in natural light. In a few cases where a soil pit already existed, this was used, as it was generally taken to a greater depth than could be accomplished otherwise. The use of roadside exposures was avoided.

It was decided early in the planning of the fieldwork that the soil sampling procedure should be extended beyond the excavation of a single soil pit and the abstraction of analytical samples from this. This was for the following reasons:-

- Forest soils are known to exhibit variation from point to point within the confines of an apparently uniform site, and it was felt to be desirable to obtain an average value for the chemical variables, which would be representative of the site as a whole.

- Removal of loose samples from a soil pit does not provide any information about soil bulk density, which is essential in calculating nutrient supply spatially. It is known to be problematic to obtain a reliable separate measure of bulk density in the laboratory, and the sampling procedures required are onerous.

Hence it was desirable to devise a method of soil sampling which could be carried out at a number of points within the site being studied and which would yield volumetric samples. The obvious approach was soil core sampling. However the experience of such methods in forest soils was not particularly encouraging as a number of problems had been identified:-

- Obstruction of the corer or disruption of the sample by stones in the profile
- Difficulty of driving a corer into dense soil and resulting core compression
- Difficulty of withdrawing the corer from the soil and associated risk of the core sample dropping back.

For these reasons it was decided to use a power-assisted soil coring system designed for use in commercial soil survey, which was rated as capable of sampling soils on ex-industrial sites, where rubble and other disruptive objects are frequent [rather than one suitable only for homogenous agricultural loams]. This system was supplied by Eijelkamp in the Netherlands, and essentially consisted of three parts (a) a cylindrical steel corer of 50cm length with a hardened steel cutting ring, (b) a petrol driven reciprocating hammer and (c) a lever-based system for withdrawing the corer from the ground. The use of this equipment meant that a large number of components had to be carried to and around the working site, some of them heavy, which, in turn, imposed the above-mentioned requirement to get a vehicle close to the site. However the sampling performance obtained was very satisfactory indeed, in the following respects:-

- Stones did not generally affect the creation of the core sample. Small stones were incorporated without core disruption. Larger soft stones [e.g. sandstone, flints] were cut through by the corer, in some cases creating complete discs up to 2-3cm thick, which slipped up inside the corer without interrupting the creation of the cylindrical sample. Large hard stones such as granite did occasionally obstruct the corer mouth, and had to be knocked out before a repeat core was taken.

- The rapid succession of small blows delivered by the mechanical hammer appeared to facilitate the easy entry of the corer into the soil, with physical force by the operator rarely being required. No compression of the soil column was observed to occur.

- The removal of the corer from the soil with the reverse-locking lever device was straightforward and again did not require brute force. In very loose soils there was some difficulty with the lower stony horizon dropping back, especially at the end of the very dry season of 1995, and when sampling littoral sand profiles. This could usually be overcome by twisting the corer in the ground, prior to withdrawal, to break the base surface adhesion, but occasionally repeated re-coring was required to obtain sufficient analytical material from the base layer.

In carrying out the sampling, two auger diameters were employed [~ 90 mm and ~ 65 mm]. The former was used for the vast majority of sites, with the smaller corer found to be best for very loose soils such as littoral sand. For most sites nine core samples were taken, but this was reduced to a minimum of six samples on a small proportion of sites where conditions were adverse [very loose soil, poor weather, excessive stoniness]. The coring locations were laid out in a geometric [row] pattern designed to provide even coverage of the site area [usually rectangular, and of the order of 0.1 ha in extent]. Sites were selected to avoid large-scale internal variations in soil conditions, and the soil type was almost always uniform for the site as a whole. Small-scale variations in soil nutrient conditions [operating over the scale of few metres] should be accounted for by the multi-point sampling and subsequent pooling of samples.

Each core sample was divided into three "layer" samples, corresponding to the major soil horizons or combinations thereof [where a separable organic layer was present, this alone formed the upper sample layer]. The thickness of each of the three layers in each core was measured with a steel tape and recorded. If the total length of the core fell short of the target 50 cm, this was noted. The three layer samples were then pushed out into separate labelled polythene bags. The corresponding layers from each core sample were pooled to create three bagged samples for the site as a whole. Although it might have been preferable to analyse the individual core samples separately to produce a measure of soil chemical spatial variability, the laboratory workload generated would have been too great. At the end of the core sampling for each site, each of the bagged samples was re-mixed on a ground sheet to ensure that it was homogeneous as to origin within the site. A small laboratory sub-sample was then taken [some 1-2 kg] and kept in a smaller, sealed and labelled plastic bag. This was placed in an insulated cool-box [re-charged with frozen brine-packs daily] until it could be transferred to a cold store on return to the laboratory. The remainder or "bulk" sample was retained at ambient temperature in the larger bags.

On return to the laboratory, both "bulk" and laboratory samples were weighed as soon as possible. On certain of the longer field trips it proved necessary to reduce the mass of soil in the "bulk" samples to facilitate transport back to base. In these cases the "bulk" samples were weighed complete using a digital balance taken for the purpose, and established in some convenient local facility [e.g. a church hall or local F.C. workshop]. The "bulk" sample was then divided, with a representative part being retained for determination of stone content and the remainder discarded locally. Depending on the soil type, the mass of soil yielded by a site could be up to 50 kg.

On return to the laboratory the "bulk" samples [complete or partial] were treated as follows:-

- Weighed on receipt in the field-moist condition
- Air-dried in an electrically heated cabinet for some days

- Sieved to a grade of 2mm using a powered "tumbler" with iron pestle bars
- The separated stones weighed in the air-dried condition
- The fines retained in the air-dried condition as an analytical reserve

In a few cases soils produced aggregates, which were harder than the associated stones, and hence not separable as described without pulverising the stones. In these cases a hand-sorting method was employed to isolate the stones by visual means. Stone-free organic horizon samples did not require to be sieved.

On return to the laboratory the laboratory samples were treated as follows:-

- Weighed on receipt in the field-moist condition
- Placed in cold-store [maintaining 1 - 4 °C]
- Pushed through an Endecott 2mm brass test sieve in the field-moist condition
- The stones separated were oven-dried for 24 hours at 80-90 °C and weighed
- The fines were immediately returned to the cold-store to await analysis

Certain wet and/or heavy-textured soils were very difficult to handle in this way at the laboratory and some modifications had to be made:-

Either:-

- Remove all stones >2mm visually, wash clean and then oven-dry and weigh as above. Process sufficient fines for analysis [300-400g], using a coffee grinder to break down aggregates to a grade which would pass the 2mm sieve.

Or:-

- Push sufficient fines for analysis through the sieve, but do not attempt to de-stone the remainder of the sample. Assume that its stone mass fraction is the same as that for the "bulk" sample, determined as described above.

In all cases, coarse organic material (such as large diameter roots, rhizomes, worms, bulbs and tenacious turf), was discarded from the analytical sample, as it could not readily be processed in the way described, and was unlikely to yield extractable nutrients. Other organic materials were broken down to pass the sieve at 2 mm, and included for analysis.

The steps described allowed the following soil physical parameters to be computed for each layer from each site:-

- Total mass of field-moist soil per hectare
- Total field-moist soil bulk density
- Dry stone mass as a fraction of field-moist total soil mass
- Total mass of field-moist fine earth per hectare [required to calculate nutrient quantities]

Where the base layer had not been able to be sampled to a depth of 50cm one of the following approaches was applied:-

- If the evidence from the soil pit suggested that the soil profile continued to a depth of 50cm, the mass of soil collected from the bottom layer was extrapolated pro-rata to indicate what it would have been for complete cores. This usually occurred where the base layer became too loose to core easily in its lower part.

- If the impediment was considered to be bedrock then the collected material was assumed to be all that was present of the base layer and the un-weathered rock assumed to make no nutrient contribution.

4.3 Field results of soil sampling - the mineral soil and humus

Please refer to Figure 4.3.1. This shows details of the 70 sites sampled in terms of (a) soil type (and soil type code) after the Forestry Commission scheme, (b) humus type after the British Columbia scheme, (c) humus type after the French scheme, (d) estimated soil moisture regime within the Ecological Site Classification scheme and estimated rooting depth.

It will be noted that the following main soil types [codes] were sampled:- brown earth [1], podzol [3], iron-pan soil [4], ground-water gley [5], peaty gley [6], surface-water gley [7], limestone-derived soil [12], ranker [13] and littoral soil [15]. It is considered that this includes all the major types of soil in use for forestry in Great Britain, with the exception of deep peats. These last were deliberately excluded for the reasons stated earlier. Man-made soils of category [2] were also not included. Within the sites sampled the brown earths, podzols and limestone-derived soils are the most heavily represented. This reflects the site selection criteria described previously. However, it should be stressed that the main upland and impeded-drainage soil types were sampled within the programme.

It is felt that soils have been sampled which would be expected to fall into each of the proposed main sequence nutrient classes [very poor, poor, medium, rich, very rich], although coverage of the classes was not uniform. It would have been desirable to sample more sites in the very poor and very rich classes, in addition to the carbonate sites mentioned in Chapter 3. The soil nutrient classification produced from this work will continue to be refined by the output of further site sampling in the future, which will focus on these parts of the range.

It will be noted that a wide range of humus types was sampled. These ranged from very infertile humimors and hemimors [BC system] to extremely rapidly decomposing eumulls [French system]. A small number of hydromorphic forms were sampled from both ends of the fertility spectrum. It will be observed that the classes to which the

Figure 4.3.1

Site details - soil type, humus type, moisture regime and rooting depth

CODE	SOIL TYPE	FC CODE	HUMUS FORM [BC]	HUMUS FORM [F]	SMR	ROOTING DEPTH cm
ABF 1	LITTORAL SAND	15	MORMODER	HEMIMODER	M	>80
ABF 2	TYPICAL IRONPAN	4	HUMIMOR	MOR	M	~40
AE 1	ALLUVIAL BR. EARTH	1v	MULLMODER	DYSMULL	M	~50
AE 2	ALLUVIAL BR. EARTH	1v	VERMIMULL	MESOMULL	M	~30
AWE 1	TYPICAL PEATY GLEY	6	HUMIMOR	MOR	W	
BAL 1	ALLUVIAL BR. EARTH	1v	HEMIMOR	MOR	F	~50
BCH 1	ALLUVIAL G-W GLEY	5v	MULLMODER	DYSMULL	VM	>50
BCH 2	TYPICAL BR. EARTH	1	MORMODER	DYSMODER	F	~35
CER 1	UPLAND BR. EARTH	1u	RHIZOMULL	OLIGOMULL	F	~60
CHT 1	ARGILLIC BR. EARTH	12t	VERMIMULL	MESOMULL	SD	>70
DEN 1	TYPICAL BR. EARTH	1	VERMIMULL	MESOMULL	F	>70
DEN 2	TYPICAL BR. EARTH	1	MULLMODER	DYSMULL	F	>55
DEN 3	TYPICAL BR. EARTH	1	VERMIMULL	MESOMULL	SD	>60
DEN 4	BROWN S-W GLEY	7b	VERMIMULL	EUMULL	M	>50
DEN 5	TYPICAL BR. EARTH	1	VERMIMULL	OLIGOMULL	SD	~80
DEN 6	TYPICAL BR. EARTH	1	VERMIMULL	MESOMULL	F	>50
DEN 7	PODZOLIC S-W GLEY	7z	MORMODER	HEMIMODER	M	~50
DST 1	ARGILLIC BR. EARTH	12t	VERMIMULL	MESOMULL	F	>60
DOW 1	TYPICAL S-W GLEY	7	MULLMODER	HYDROMODER	M	~70
DOW 2	ARGILLIC BR. EARTH	12t	VERMIMULL	MESOMULL	SD	~50
DOW 3	PODZOLIC G-W GLEY	5z	HEMIMOR	MOR	M	>70
DOW 4	HARDPAN PODZOL	3m	HEMIMOR	MOR	MD	>70
DOW 5	CALCAR. BR. EARTH	12b	VERMIMULL	EUMULL	F	~50
DOW 6	BROWN S-W GLEY	7b	VERMIMULL	MESOMULL	M	>50
GTN 1	TYPICAL BR. EARTH	1	MULLMODER	OLIGOMULL	F	~70
INV 1	PODZOLIC IRONPAN	4z	HEMIMOR	MOR	F	~50
INV 2	UPLAND BR. EARTH	1u	MORMODER	DYSMULL	F	>60
KCD 1	TYPICAL BR. EARTH	1	MORMODER	AMPHIMULL	F	~60
KCD 2	INTERGRADE IRONPAN	4b	HUMIMOR	AMPHIMULL	M	~50
KIN 1	TYPICAL PEATY GLEY	6	HUMIMOR	MOR	W	
KIN 2	INTERGRADE IRONPAN	4b	HUMIMOR	MOR	M	
LAK 1	TYPICAL S-W GLEY	7	LEPTOMODER	AMPHIMULL	M	~40
LAK 2	TYPICAL BR. EARTH	1	MULLMODER	DYSMULL	F	>40
LAK 3	TYPICAL BR. EARTH	1	MULLMODER	HEMIMODER	F	>50
LCH 1	INTERGRADE IRONPAN	4b	RESIMOR	MOR	VM	~55
LND 1	LITTORAL SAND	15	HEMIMOR	HEMIMODER	F	>50
LND 2	LITTORAL SAND	15	MULLMODER	HEMIMODER	M	>80
LOT 1	TYPICAL BR. EARTH	1	MULLMODER	DYSMULL	F	>60
LOT 2	UPLAND BR. EARTH	1u	MORMODER	DYSMULL	F	>100
LWT 1	PODZOLIC RANKER	13z	HEMIMOR	AMPHIMULL	SD	~20
LWT 2	UPLAND BR. EARTH	1u	MULLMODER	DYSMULL	F	>50
MCH 1	TYPICAL BR. EARTH	1	VERMIMULL	OLIGOMULL	F	>50
MCH 2	CALCAR. S-W GLEY	7k	VERMIMULL	HYDROMULL	VM	>50
MID 1	PODZOLIC G-W GLEY	5z	HUMIMOR	MOR	M	~85

Figure 4.3.1
Site details - soil type, humus type, moisture regime and rooting depth

CODE	SOIL TYPE	FC CODE	HUMUS FORM [BC]	HUMUS FORM [F]	SMR	ROOTING DEPTH cm
MOR 1	PODZOLIC BR. EARTH	1z	MULLMODER	EUMODER	F	>70
MOR 2	LITTORAL SAND	15	LEPTOMODER	MOR	M	~40
MOR 3	PODZOLIC IRONPAN	4z	HEMIMOR	HEMIMODER	M	~30
NEW 1	TYPICAL BR. EARTH	1	RESIMOR	MOR	F	>50
NTH 1	ARGILLIC BR. EARTH	12t	VERMIMULL	MESOMULL	F	>60
NTH 2	CALCAR. S-W GLEY	7k	VERMIMULL	EUMULL	M	~50
NYM 1	BROWN G-W GLEY	5b	MORMODER	AMPHIMULL	VM	~45
SEA 1	TYPICAL PODZOL	3	RESIMOR	MOR	F	~50
SEW 1	UPLAND BR. EARTH	1u	MORMODER	DYSMULL	F	>60
SFD 1	BROWN S-W GLEY	7b	MULLMODER	DYSMULL	M	~50
SNT 1	TYPICAL PEATY GLEY	6	HUMIMOR	HYDROMOR	W	>80
SWD 1	ARGILLIC BR. EARTH	12t	VERMIMULL	EUMULL	M	>60
SWD 2	TYPICAL BR. EARTH	1	RESIMOR	MOR	MD	>70
SWD 3	PODZOLIC BR. EARTH	1z	HEMIMOR	MOR	MD	>65
SWP 1	TYPICAL BR. EARTH	1	LEPTOMODER	DYSMULL	F	~90
SWP 2	INTERGRADE IRONPAN	4b	MORMODER	HEMIMODER	M	~60
SWP 3	TYPICAL BR. EARTH	1	MORMODER	HEMIMODER	F	~60
TAY 1	UPLAND BR. EARTH	1u	RHIZOMULL	OLIGOMULL	F	>50
TAY 2	BASIC BR. EARTH	1d	VERMIMULL	EUMULL	M	~50
THT 1	ARGILLIC BR. EARTH	12t	MULLMODER	OLIGOMULL	F	~70
THT 2	HARDPAN PODZOL	3m	HEMIMOR	MOR	MD	~40
THT 3	CALCAR. BR. EARTH	12b	VERMIMULL	EUMULL	M	>55
THT 4	ARGILLIC BR. EARTH	12t	LEPTOMODER	HEMIMODER	SD	>90
THT 5	ARGILLIC BR. EARTH	12t	RESIMOR	MOR	SD	>90
THT 6	PODZOLIC BR. EARTH	1z	MORMODER	DYSMODER	SD	>90
WLD 1	PODZOLIC S-W GLEY	7z	HEMIMOR	MOR	F	~60

Key to Figure 4.3.1

FC code

These are Forestry Commission soil surveying codes corresponding directly to the soil types listed.

SMR = Soil moisture regime

MD = Moderately dry
SD = Slightly dry
F = Fresh
M = Moist
VM = Very moist
W = Wet

humus profiles are assigned under the two systems are very strongly inter-related, especially in the central part of the range. At the infertile end the BC system provides greater resolution, whilst at the fertile end the French system is more informative. In field application the two systems proved each to have merits and de-merits. The British Columbia system perhaps offers more easily-observed criteria for classification, but suffers from a reliance on what seem excessively strict thickness "cut-offs", which may not be entirely applicable in British forest conditions, where many humus profiles are immature. The French system relies to a greater degree on an interpretation of the humification process rather than dimensional status. This allows the surveyor more discretion, but calls for a skilled examination of the humus, usually with the aid of a hand-lens. This should ideally be carried out in the field as the dimensional record made for the British Columbian system is not sufficient to apply the French system later with absolute confidence.

The soil moisture regime class recorded for each site was arrived at by a subjective field assessment. The national maps of climatic moisture deficit required to make numerical calculations of S.M.R. are not yet available for all the regions where sites were located. However it is felt that the classes given are a fair reflection of the true regime. The main difficulty with subjective assessment arises at the drier end of the range.

The rooting depths recorded for each site were arrived at by examination of the soil pit for visible tree roots. For the purposes of the work on soil nutrient regime, the important factor to note is that most of the profiles had rooting depths of at least the 50cm soil sampling depth. Where rooting clearly continued below the base of the soil pit, it is recorded as "greater than" whatever that depth was. In some cases it may be lm or more.

A set of detailed site and soil description sheets for each site is contained in Appendix1. A schedule of the soil physical parameters is contained in Appendix 2.

4.4 Photographic record of soil sampling work

See Figures 4.4.1 to 4.4.10

Figure 4.4.1 Site: MCH2 - Wigmore Rolls, Welsh Marches
Soil type: Calc. surface-water gley [7k] Humus type: Eumull

Figure 4.4.2 Site: DEN6 - Forest of Dean
Soil type: Brown earth [1] Humus type: Mesomull

Figure 4.4.3 Site: THT1 - Thetford Forest
Soil type: Argillic brown earth [12t] Humus type: Oligomull

Figure 4.4.4 Site: LND2 - Pembrey Forest, South Wales
Soil type: Littoral sand [15] Humus type: Moder

Figure 4.4.5 **Site: DOW1 - Alice Holt Forest, Surrey**
Soil type: Surface-water gley [7] **Humus type: Moder**

Figure 4.4.6 Site: THT2 - Thetford Forest
Soil type: Hardpan podzol [3m] Humus type: Mor

Figure 4.4.7 Site: MOR3 - Teindland Forest, Moray
Soil type: Podzolic ironpan [4z] Humus type: Mor

Figure 4.4.8 Eijelkamp soil coring "drill-kit"

Figure 4.4.9 **Insertion of auger using percussion hammer**

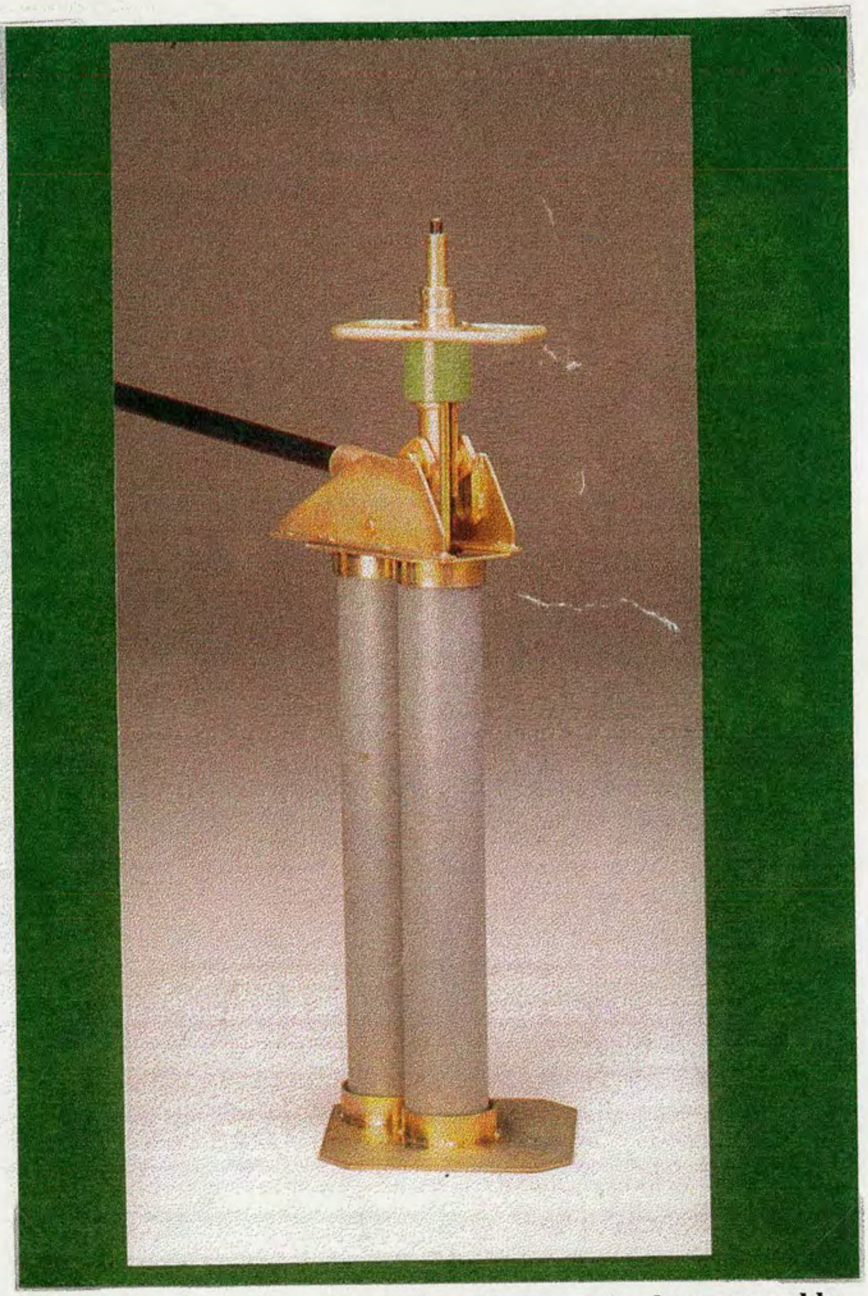


Figure 4.4.10 **Retraction of auger using lever assembly**

5. VEGETATION SAMPLING - METHODOLOGY AND FIELD RESULTS

5.1 Literature review of vegetation sampling and interpretation techniques

A review of the literature relating to vegetation sampling and interpretation will now be presented. This will be sub-divided into the following categories:- (a) interpretation of vegetation structure and composition, (b) use of vegetation as an indicator in forest site classification and (c) methods of field sampling. Material of a mainly statistical nature will be held over for the literature review in Chapter 7.

Vegetation structure and composition

Vegetation science in its earlier phase was essentially restricted to taxonomic botany and associated evolutionary issues. However, since the early twentieth century the discipline of vegetation ecology has developed. This has been primarily concerned with the structural and compositional development of vegetation assemblages. The initial or "classical" school of thought in vegetation ecology was one which placed emphasis on the concept of persistent synecological associations between "communities" of species, frequently to be found occurring together [often as so called "climax" communities, which would remain constant in the absence of external perturbation or "disturbance"]. This approach was developed in Continental Europe and came to be known as the "Montpellier school". One of the most influential expressions of these ideas was by Braun-Blanquet (1932) in his *"Plant sociology: the study of plant communities"*. Their influence can be seen in a wide variety of work, especially in Europe between the 1930's and the 1970's. Passarge & Hoffmann (1964) discuss the species groups of Central Europe. Much of the work of Ellenberg [e.g. Ellenberg (1988)] remains firmly based within the phyto-sociological framework. In Britain, a related, but less formalised, approach to vegetation classification has been preferred [Poore & McVean (1957), McVean & Ratcliffe (1962)]. The continuing influence of these ideas can still be seen in work such as the National Vegetation Classification [Rodwell (1991), Whitbread & Kirby (1992)], and other proposed classifications of woodland vegetation [Bunce (1982, 1989) and Peterken (1993)]. In turn, they still inform habitat management and conservation guidance, for example with regard to the creation of new native woodlands [Rodwell & Patterson (1994)].

It was always "taken as read" that such vegetation communities arose in response to abiotic factors and gradients in these factors. However, the nature of these dependencies was never clearly expressed, and there was often an un-stated assumption of higher-order interspecies synergistic interaction acting to maintain the structure of these communities against moderate change in the abiotic environment. The great advantage of this approach to vegetation structure was that it simplified the analysis as compared with a single-species response model, by reducing the degrees of freedom, and produced recognisable vegetation "entities". This was all but essential in the period before the availability of computerised processing of vegetation data. The marked disadvantages of the approach were its subjectivity, rigidity and poorly explained functional basis, which essentially restricted its application to natural or semi-natural contexts where disturbance had been absent for a long period. For example, in Great Britain, it was mainly applied to such contexts as arctic-alpine montane vegetation and native woodland remnants.

For the past two to three decades the "classical" approach has been seen to be in decline in the face of what might be termed "functional" or "factorial" approaches to vegetation analysis. These emphasise the autecological response of individual species to identified abiotic parameters, and the eco-physiological basis underlying these responses. This leads to apparent species "groupings" or "associations" which are "marriages of temporary ecological convenience", and lack the synecological permanence of classical communities. The reasons for the development of this approach are essentially three-fold:- (a) advances in the field of plant physiology and a concomitant desire for a more objective, quantified, description of vegetation behaviour, (b) the need to apply the results of vegetation analysis in transient and disturbed contexts [what are known as seral or "arrested successional" situations] and (c) the advent of electronic computerised techniques for analysis of complex vegetation data and for modelling vegetation development. The last factor has essentially diminished the advantage of simplification, which previously favoured the classical approach. [A review of the literature relating to such statistical processing techniques will be presented in Chapter 7 infra].

Grime, Hodgson & Hunt (1988) provide an excellent overview of the developments highlighted above, in their text *"Comparative plant ecology"*. An early indication of the onset of the new functional, factorial approach is given by Major (1951). Maslove (1989) considers issues of forest vegetation heterogeneity and small-scale pattern within this context. A considerable volume of work has been pursued in Great Britain with regard to the relationship between vegetation and soil factors [Ferreira (1963) and Birse & Robertson (1976)]. It should be noted that some work of this kind was included in the preparation of the National Vegetation Classification [Rodwell (1991)], and indeed Peterken's classification of woodland stand-types [Peterken (1993)]. However, both of these classifications were ultimately based on a combination of divisive cluster analysis of the vegetation sample data and on subjective interpretation thereof.

A major strand in the development of functional vegetation analysis has been the proposal of various sets of species indicator values for prediction of environmental factors by examination of the vegetation species composition. By far the best known of these proposals is that of Ellenberg (1974, 1988) and Ellenberg *et al* (1992) applicable initially to Central Europe. Ellenberg produces a set of values on an ascending integer scale of 1 to 9 for several environmental factors, notably soil reaction [base status] - the "R" value, soil nitrogen availability - the "N" value, and soil moisture - the "F" value. Several authors have considered the most effective way to put these values to use in environmental diagnosis [Ellenberg (1992), ter Braak & Barendrecht (1986), ter Braak & Gremmen (1987) and Thompson *et al* (1993)]. Also see Persson (1981). Weighted averaging, on the basis of species abundance [cover or frequency], has emerged as the main mechanism for producing site indicator values.

Vegetation as an indicator in forest site classification

As discussed earlier, vegetation has been widely used as an indicator of abiotic site conditions for the purpose of forest site classification. As already seen, there is a strong tradition of this in Continental Europe. For Germany: Klock (1970) and Sebald (1964); For France: Duchaufour (1960) and Rameau, Mansion & Dume (1989, 1993); For Belgium: Noirfalise (1984); For Hungary: Csapody *et al* (1963); For Scandinavia: Cajander (1913, 1926 & 1949), Lahti (1995), Nieppola (1986, 1993) & Sarasto (1964). For the United States and Canada: Gagnon & MacArthur (1959), Klinka *et al* (1989), Loucks (1962). For Australia: Hammer (1979)

In Great Britain, the earliest work found is that of Muir & Fraser (1939) in Aberdeenshire. Anderson's approach is perhaps the best known, certainly amongst foresters, as opposed to vegetation ecologists [Anderson (1950)]. Workers such as Ovington (1955) continued to emphasise the value of the use of ground vegetation through the 1950's.

In more recent years a number of approaches have been made to capture the diagnostic capacity of vegetation using species indicator values and multi-variate statistical approaches, rather than through vegetation community/ site-type matching on the European model. Rogister (1978) used Ellenberg values in Belgian forests for this purpose, as have Hawkes, Pyatt & White (1997) in Great Britain, in their pilot investigation for the present study. Gegout & Houllier (1993) used an approach comparable to the present study in north-eastern France, but did not utilise Ellenberg values. Hill, Bunce & Shaw (1975) carried out a small study in Scottish pinewoods.

Methods of field vegetation sampling

There are two main approaches that can be applied to the systematic sampling of vegetation. These might be termed "confirmatory sampling" and "representative sampling".

In confirmatory sampling the vegetation assemblage, for example a woodland site, is allocated to one of a pre-determined set of possible classes by inspection. These classes usually form part of an established scheme, and the decision is based on the co-presence of a set of "indicator species" for that community. Their relative abundance [usually in terms of frequency] is often implicitly considered. This type of surveying requires an experienced ecologist who can recognise the "feel" of particular communities, as some of the diagnostic species may be absent in any given situation. A set of quadrat samples is then examined to confirm and evidence the reasonableness of the surveyor's decision. These are not necessarily placed randomly or systematically, as their intention is to confirm by occurrence the presence of a particular community type. Woodland surveying for the National Vegetation Classification is usually carried out by this technique. The standard method is to use one 50 x 50 m quadrat for the canopy layer, containing five 4 x 4 m quadrats for the shrub and field layers [Cooke, pers. comm.] The species frequency data collected from the quadrats can then be used to create a constancy table of the type presented in Rodwell (1991). A comparison with these standard tables for each likely community will confirm the "best-fit". This process of comparison can now be carried out automatically using the computer programmes "MATCH" [Unit of Vegetation Science, University of Lancaster] or "TABLEFIT" [Institute of Terrestrial Ecology, Monks' Wood]. However, it remains necessary to be able to recognise an area of homogeneous vegetation in the field.

In representative survey, the intention is that only the information collected within the sample will speak for the vegetation of the site. There is no implicit requirement for an inspection of the site as a whole as described above, and less need for the surveyor to be able to recognise vegetation communities as entities. However the sample must be designed in such a way as to be statistically representative of the site as a whole. This generally encourages survey at a greater number of points to account for vegetation heterogeneity, but usually with a smaller quadrat size as it is not so vital to "detect" rare but specifically indicative species for particular communities. A quadrat of 0.5 x 0.5 m, 1 x 1 m or 2 x 2 m can be used depending on the vegetation "scale of structure" i.e. a small quadrat would be used for a bryophyte carpet and perhaps a 2 x 2 m quadrat for woodland tall herb vegetation. There is almost always some element of compromise to be arrived at. The arrangement of quadrats should be either random or geometrical [where the vegetation does not manifest any confounding geometrical patterning].

It is possible to use representative surveying to allocate vegetation to phyto-sociological communities such as the N.V.C. [mainly now by computer], where the surveyor is less expert, but the results are often not as apparently clear-cut as those which are based on an inclusive examination in the field. The main reason for this is that the "site" within which the sampling was carried out may not be uniform as to community type. Representative surveying is more usually used where the intention is to process the raw species data numerically. This can be by the allocation of indicator values to species [and hence to the site] or by the use of multivariate statistical processing on the species abundance data. The interest in these cases is in "emergent" features of the data themselves, rather than in correspondence with pre-recognised community types.

The recording of quadrat data can usually be done in one of three ways:- (a) by presence only, (b) by frequency/ constancy or (c) by ground cover fraction . The latter can be either as a raw percentage/ ratio or as a "Domin score" which uses a frequency adjusted logarithmic abundance scale. For the purposes of community recognition either presence/ absence or frequency data are all that is usually required. These avoid the need for an estimate of cover to be made. However for the purpose of numerical analysis an abundance measure is to be preferred.

5.2 Description of vegetation sampling methods

It was decided that the maximum information possible regarding the species composition of the ground vegetation should be collected at each site, consistent with the time available for survey. It was considered that this would be accomplished by collecting the data in the form of ground-cover percentage for each species [which, in multi-layered vegetation, could sum to more than 100%]. The cover of each species was considered separately for both the field and ground layers where these were identifiable. Frequency and presence/absence forms of the survey data could then readily be produced if desired.

It was decided to carry out such a survey for nine 2 x 2 m quadrats within the sampling site area, coincident with the locations of the soil core sampling points. Hence the survey conducted was rather more intensive than that described above for the National Vegetation Classification. Sampling sites were selected which displayed reasonably consistent ground vegetation assemblages, although smaller scale "patchiness" is a feature of many vegetation types. Hence this higher intensity of vegetation sampling was required to account for such small-scale variation within a representative survey strategy.

Where identification of species could not be accomplished by inspection in the field, they were allocated a descriptive code against their abundance, and later identified with the aid of a suitable Flora. For flowering plants Blamey & Grey-Wilson (1989) was used, for grasses Hubbard (1992) and for ferns and allies Jermy & Camus (1991). Phillips (1980) was also helpful. Nomenclature was held consistent with Stace (1991). Computer plant identification software was used on a trial basis, but, in its present form, did not prove to offer any advantage as compared to an illustrated printed Flora. It was decided that bryophytes should only be recorded as an aggregated cover fraction and not by species, although the principal species were noted for bryophyte-rich sites. The reasons for this were two-fold:- (a) it was felt that bryophytes would not be reliable as indicators of the nutrient supply in the top 50cm of soil, due to their restricted rooting depth, and (b) it was considered that it would be over-ambitious to include a requirement for bryophyte identification in the early stages of operational implementation of the E.S.C. system. The use of bryophytes as indicators is embraced by other systems overseas, and could be contemplated as a component of E.S.C. in the future.

The vegetation abundance data collected was used initially in three ways to assist in the characterisation of each site:-

- The closest-fit National Vegetation Classification woodland sub-community was decided for the site. This was carried out using the species lists/ constancy tables for each sub-community provided by Rodwell (1991). The canopy species was considered only where the woodland was semi-natural [two sites], otherwise only the ground vegetation was taken into account [but including any natural regeneration of the canopy species]. For some sites, with only a few species present, it was problematic to decide between two or more sub-communities as to which was the best fit, and some judgement had to be applied.

- The Ellenberg species indicator values were used to calculate abundance-weighted mean site indicator values for base status [reaction] - R, and nitrogen supply - N on a scale of 1 to 9 [ascending status]. This calculation used all species present in the quadrats for which Ellenberg values exist and was carried out using a custom-designed spreadsheet incorporating the Ellenberg values. [In a few cases the species list for a site was too long for the spreadsheet to utilise, and a few very low abundance species had to be discarded to overcome this. The effect of this on the calculated mean values for the site is considered to be negligible.] The decision to weight the Ellenberg species indicator values by cover abundance inherently places emphasis on the indicative potential of the more dominant species, which are readily identifiable in practical application of the methodology. The pilot study by Hawkes, Pyatt & White (1997) suggested that this method produced somewhat more reliable predictions of soil nutrient regime than did weighting by species frequency. The use of the Domin score system for weighting is a possible alternative approach, which may be appraised in future studies.

- The vegetation of each site was assigned to one of ten "visually-dominant vegetation types". This allows for a preliminary positioning of a site on the trophic scale, prior to conducting a detailed survey of the vegetation

5.3 <u>Field results of vegetation sampling</u>

A wide range of vegetation types were sampled, although they were observed to fall into a number of major categories of "visually-dominant vegetation type" which gave the first impression of a site. It is felt that vegetation types corresponding to the whole range of soil nutrient regime were sampled [excluding carbonate soil regimes]. However, there are certainly other dominant vegetation types in British woodlands which were not sampled, for example those characterised by *Hedera helix* [L.] and by *Carex* species. These are considered likely to be coincident with those which were sampled, in terms of their soil nutrient tolerance range.

The sites were characterised by the following National Vegetation Classification woodland communities and sub-communities, based on ground vegetation alone [for plantations] [Rodwell (1991)]:-

W4 ***Betula pubescens - Molinia caerulea*** **woodland**

W4b *Juncus effusus* sub-community

W7 ***Alnus glutinosa - Fraxinus excelsior - Lysimachia nemorum*** **woodland**

W7a *Urtica dioica* sub-community

W7c *Deschampsia cespitosa* sub-community

W8 ***Fraxinus excelsior - Acer campestre – Mercurialis perennis*** **woodland**

W8a *Primula vulgaris - Glechoma hederacea* sub-community

W8b *Anemone nemorosa* sub-community

W8c *Deschampsia cespitosa* sub-community

W8e *Geranium robertianum* sub-community

W8f *Allium ursinum* sub-community

W10 ***Quercus robur - Pteridium aquilinum – Rubus fruticosus*** **woodland**

W10a Typical sub-community

W10b *Anemome nemorosa* sub-community

W10c *Hedera helix* sub-community

W10d *Holcus lanatus* sub-community

W10e *Acer pseudoplatanus - Oxalis acetosella* sub-community

W11 ***Quercus petraea - Betula pubescens – Oxalis acetosella*** **woodland**

W11a *Dryopteris dilatata* sub-community

W11c *Anemone nemorosa* sub-community

W11d *Stellaria holostea - Hyperichum pulchrum* sub-community

W14 ***Fagus sylvatica – Rubus fruticosus*** **woodland**

W16 ***Quercus spp. - Betula spp. – Deschampsia flexuosa*** **woodland**

W16a *Quercus robur* sub-community

W16b *Vaccinium myrtillus - Dryopteris dilatata* sub-community

W17 ***Quercus petraea – Betula pubescens – Dicranum majus* woodland**

W17b Typical sub-community

W17d *Rhytidiadelphus* sub-community

W18 ***Pinus sylvestris – Hylocomium splendens* woodland**

W18a *Erica cinerea -Goodyera repens* sub-community

W18b *Vaccinium myrtillus - Vaccinium vitis-idaea* sub-community

W9 *Fraxinus excelsior - Sorbus aucuparia - Mercurialis perennis* woodland did not feature at any of the sites sampled.

The range of abundance-weighted Ellenberg site mean indicator values recorded was:-

R-value:	**1.04**	**to**	**7.18**
N-value	**1.04**	**to**	**8.57**

The range of possible single-species values is from 1 to 9 in each case. For both Ellenberg values, the range from 3 to 6.5 is the most heavily populated by the sample sites.

The sites sampled were seen to divide naturally into the following ten "visually-dominant vegetation-types":-

Type A ***Calluna vulgaris* or *Erica* spp. [L.] dominant**

This is an easily identifiable type of very low fertility sites, corresponding to the W18 N.V.C. communities. It is the only type where these species are frequent or abundant. Other "pinewood" species such as *Vaccinium* spp. and *Goodyera repens* [(L.) R.Br.] may be present.

Type B ***Molinia caerulea* dominant**

This type occurs on infertile, wet soils and corresponds to W4 and some mire [M] communities. *Molinia caerulea* is required to be dominant [>50% cover]. Sites with a more minor component of the species are referred to Type D, for example.

Type C ***Deschampsia flexuosa* dominant**

This is a type mainly found on freely draining upland sites of low soil fertility. A dense turf-mat of the grass is often present. Accompanying species are usually *Galium saxatile* [L.], *Oxalis acetosella* [L.] and on occasion a minor component of *Dryopteris* spp [Adans.] or *Pteridium aquilinum*. It can be taken to correspond to either W16 or W17.

Type D ***Pteridium aquilinum* dominant**

This is a type mainly found on freely draining lowland sites of low soil fertility. *Pteridium aquilinum* is strongly dominant, often forming a canopy at 1-1.5 m height. *Deschampsia flexuosa* can be frequent, but *Rubus* spp. [L.] are at most a minor component. This type corresponds to W16.

Type E ***Rubus fruticosus* [L.agg.]dominant alone/ with *Pteridium aquilinum***

This is a type mainly found in the lowlands on moderate soil fertility sites. It corresponds to the less fertile sector of the W10 community. *Rubus fruticosus* must be dominant, *Pteridium aquilinum* may be jointly so. Species diversity is often relatively low, but the vegetation may be very lush. *Dryopteris* spp. should be subordinate to *Pteridium aquilinum.*

Type F ***Dryopteris spp./ Oxalis acetosella* dominant [with *Rubus* spp.]**

This type is mainly found in the uplands on moderate to high fertility sites, corresponding to the W11 community. It has variants where either *Dryopteris* spp or *Oxalis acetosella* are totally dominant [perhaps due to canopy shade conditions]. *Rubus* spp. may well be dominant also. *Pteridium aquilinum* will not usually be so.

Type G ***Holcus* spp. [L.] and/ or *Agrostis* spp. [L.] dominant**

This type is found in situations of strong light or with evidence of recent disturbance, on moderate fertility sites. A grass sward should be clearly dominant. The type may be a simplified phase of the W10 community [ref. W10d *Holcus lanatus* sub-community]

Type H **Species-rich vegetation**

This type is usually characterised by a long species list. It is found on high fertility lowland sites, and corresponds to the more fertile sector of W10 and the less fertile sector of W8. Species such as *Hyacinthoides non-scripta* [(L.) Chouard ex Rothm.], *Rubus fruticosus, Glechoma hederacea* [L.] and *Galeopsis tetrahit* [L.] are characteristic. *Mercurialis perennis* [L.] may be present, but not abundant or dominant. *Pteridium aquilinum* may still be significant.

Type I ***Mercurialis perennis* dominant**

This type is characteristic of highly fertile lowland sites, and represents the main body of W8. *Mercurialis perennis* should be dominant, with *Allium ursinum* [L.] and *Arum maculatum* [L.] possibly frequent. *Hyacinthoides non-scripta* may be abundant, but *Rubus fruticosus* and *Dryopteris* spp. should have largely faded out, as compared with Type H. An exposed mineral soil surface due to rapid humification is characteristic also.

Type J ***Urtica dioica* [L.] dominant**

This type occurs on apparently eutrophic sites. It can be read as a simplified expression of W6, W7 or W8 communities. *Urtica dioica* should be the most abundant species, and often has prolific growth. Accompanying species can be *Galium aparine* [L.] , *Galium mollugo* [L.] or *Mercurialis perennis.*

Type E and Type F are, in some cases, difficult to separate, particularly in areas of the country on the borderline between the uplands and the lowlands, where *Pteridium aquilinum* and *Dryopteris* spp. are coexistent.

For summary descriptions of the vegetation at each site see Figure 5.3.1. Detailed vegetation survey results are presented in Appendix 3, together with an example of the spreadsheet template used to calculate the abundance-weighted Ellenberg site mean indicator values.

5.4 Photographic record of vegetation sampling

See Figures 5.4.1 to 5.4.10

Key to Figure 5.3.1 and to Figures 5.4.1 to 5.4.10

Ellenberg values

R = soil base status [mR where a site mean value is being referred to]

N = soil nitrogen supply [mN where a site mean value is being referred to]

NVC Woodland sub-community/ Visually-dominant vegetation type

Please refer to the typologies set out in section 5.3 above

Figure 5.3.1
Site details - Ellenberg indicator values, N.V.C. sub-community and dominant vegetation

CODE	ELLENBERG VALUES R	ELLENBERG VALUES N	NVC WOODLAND SUB-COMMUNITY	VISUALLY DOMINANT TYPE	MAIN FIELD LAYER SPECIES
ABF 1	3.02	6.60	W11a	F	Dryopteris dilatata, Agrostis stolonifera
ABF 2	2.00	3.00	W16b	C	Deschampsia flexuosa,Vaccinium myrtillus, Blechnum spicant
AE 1	4.70	6.04	W11a	F	Dryopteris dilatata, Agrostis stolonifera, Oxalis acetosella, Rubus fruticosus
AE 2	3.97	5.93	W11a	F	Oxalis acetosella, Dryopteris dilatata, Athyrium filix-femina
AWE 1	3.40	5.40	W11a	F	Oxalis acetosella, Dryopteris dilatata, Pteridium aquilinum
BAL 1	1.88	2.33	W18a	A	Calluna vulgaris, Deschampsia flexuosa, Vaccinium myrtillus
BCH 1	3.93	5.76	W11a	F	Oxalis acetosella, Gymnocarpium dryopteris, Agrostis stolonifera
BCH 2	2.80	4.39	W10d	G	Deschampsia flexuosa, Holcus mollis, Oxalis acetosella, Pteridium aquilinum
CER 1	2.10	3.28	W17b	C	Deschampsia flexuosa, Galium saxatile Dryopteris dilatata
CHT 1	4.75	4.91	W14	E	Rubus fruticosus, Brachypodium sylvaticum, Oxalis acetosella, Holcus mollis
DEN 1	5.07	6.02	W10a	E	Rubus fruticosus
DEN 2	3.28	3.64	W10c	D	Pteridium aquilinum, Holcus mollis, Rubus fruticosus, Hyacinthoides non-scripta
DEN 3	4.68	5.08	W10e	H	Hyacinthoides non-scripta, Holcus mollis, Rubus fruticosus, Dryopteris dilatata
DEN 4	5.16	5.55	W8c	H	Rubus fruticosus, Deschampsia cespitosa, Hyacinthoides non-scripta, Dryopteris filix-mas
DEN 5	4.25	4.90	W10c	E	Corylus avellana, Rubus fruticosus, Pteridium aquilinum, Lonicera periclymenum

Figure 5.3.1
Site details - Ellenberg indicator values, N.V.C. sub-community and dominant vegetation

CODE	ELLENBERG VALUES R	ELLENBERG VALUES N	NVC WOODLAND SUB-COMMUNITY	VISUALLY DOMINANT TYPE	MAIN FIELD LAYER SPECIES
DEN 6	3.63	4.50	W10e	G	Holcus mollis, Hyacinthoides non-scripta, Rubus fruticosus, Oxalis acetosella
DEN 7	4.16	5.23	W11a	F	Rubus fruticosus, Pteridium aquilinum, Dryopteris dilatata, Deschampsia flexuosa
DST 1	6.92	6.15	W8b	H	Hyacinthoides non-scripta, Hedera helix, Anemone nemorosa
DOW 1	3.22	3.47	W10a	D	Pteridium aquilinum, Lonicera periclymenum, Rubus fruticosus
DOW 2	5.06	5.65	W8a	H	Rubus fruticosus, Hyacinthoides non-scripta, Holcus mollis, Dryopteris filix-mas
DOW 3	3.15	3.09	W4a	D	Pteridium aquilinum, Molinia caerulea, Lonicera periclymenum, Rubus fruticosus
DOW 4	3.02	3.13	W16a	D	Pteridium aquilinum, Dryopteris dilatata
DOW 5	7.05	7.09	W8a	I	Mercurialis perennis, Urtica dioica, Glechoma hederacea, Galium aparine
DOW 6	4.78	5.38	W8c	H	Rubus fruticosus, Lonicera periclymenum, Glechoma hederacea, Corylus avellana
GTN 1	3.36	3.45	W11c	D	Holcus mollis, Pteridium aquilinum, Anemone nemorosa, Rubus saxatilis
INV 1	1.39	1.64	W18b	A	Calluna vulgaris, Deschampsia flexuosa, Vaccinium myrtillus
INV 2	3.95	5.02	W11a	G	Agrostis capillaris, Dryopteris dilatata, Oxalis acetosella
KCD 1	2.01	3.02	W17d	C	Deschampsia flexuosa, Galium saxatile
KCD 2	2·33	4.39	W17d	C	Deschampsia flexuosa, Oxalis acetosella, Galium saxatile
KIN 1	1·70	2·28	W17b	A	Calluna vulgaris, Deschampsia flexuosa, Vaccinium myrtillus

Figure 5.3.1
Site details - Ellenberg indicator values, N.V.C. sub-community and dominant vegetation

CODE	ELLENBERG VALUES R	ELLENBERG VALUES N	NVC WOODLAND SUB-COMMUNITY	VISUALLY DOMINANT TYPE	MAIN FIELD LAYER SPECIES
KIN 2	3.46	5.47	W11a	F	Dryopteris dilatata, Oxalis acetosella, Deschampsia flexuosa, Dryopteris affinis
LAK 1	2.94	4.50	W11a	G	Holcus mollis, Deschampsia cespitosa, Agrostis stolonifera, Deschampsia flexuosa
LAK 2	4.67	5.09	W10d	G	Agrostis stolonifera, Holcus lanatus, Rubus fruticosus, Hyacinthoides non-scripta
LAK 3	3.89	5.75	W11a	F	Oxalis acetosella, Dryopteris dilatata, Rubus fruticosus, Deschampsia flexuosa
LCH 1	2.82	4.08	W17b	C	Deschampsia flexuosa, Oxalis acetosella, Agrostis capillaris, Deschampsia cespitosa
LND 1	4.94	6.11	W11a	F	Dryopteris dilatata, Rubus fruticosus, Carex arenaria
LND 2	5.14	6.28	W11a	F	Rubus fruticosus, Dryopteris dilatata, Dryopteris filix-mas, Hedera helix
LWT 1	3.09	4.56	W16b	D	Dryopteris dilatata, Athyrium filix-femina, Rubus idaeus, Deschampsia cespitosa
LWT 2	4.03	5.99	W11a	F	Pteridium aquilinum, Dryopteris dilatata, Holcus mollis, Deschampsia flexuosa
LOT 1	4.11	6.54	W11a	F	Pteridium aquilinum, Dryopteris dilatata, Vaccinium myrtillus, Rubus fruticosus
LOT 2	2.50	4.25	W11a	F	Dryopteris dilatata, Agrostis capillaris, Rubus fruticosus, Oxalis acetosella
MCH 1	4.27	4.20	W10b	H	Anemone nemorosa, Pteridium aquilinum, Rubus fruticosus, Euphorbia amygdaloides
MCH 2	6.92	6.30	W7c	I	Mercurialis perennis, Corylus avellana, Filipendula ulmaria, Ranunculus ficaria
MID 1	2.90	3.29	W16a	D	Pteridium aquilinum, Deschampsia flexuosa Holcus mollis, Rubus fruticosus
MOR 1	2.19	1.79	W18a	A	Erica cinerea, Deschampsia flexuosa

Figure 5.3.1

Site details - Ellenberg indicator values, N.V.C. sub-community and dominant vegetation

CODE	ELLENBERG VALUES R	N	NVC WOODLAND SUB-COMMUNITY	VISUALLY DOMINANT TYPE	MAIN FIELD LAYER SPECIES
MOR 2	1.04	1.04	W18a	A	Calluna vulgaris, Carex arenaria
MOR 3	1.05	1.06	W18a	A	Calluna vulgaris, Tricophorum cespitosum
NEW 1	3.03	2.98	W16a	D	Pteridium aquilinum, Molinia caerulea, Hedera helix, Deschampsia flexuosa
NTH 1	5.35	5.21	W10b	H	Hyacinthoides non-scripta, Rubus fruticosus, Pteridium aquilinum, Mercurialis perennis
NTH 2	6.78	7.23	W7a	J	Phalarus arundinacea, Urtica dioica, Agrostis stolonifera, Cirsium arvense
NYM 1	4.91	6.46	W11a	F	Rubus fruticosus, Dryopteris dilatata, Oxalis acetosella, Holcus mollis
SEA 1	1.28	1.22	W18b	A	Calluna vulgaris, Vaccinium vitis-idaea
SEW 1	2.06	3.11	W16b	C	Deschampsia flexuosa, Pteridium aquilinum Dryopteris dilatata
SFD 1	4.63	5.85	W10e	F	Rubus fruticosus, Teucrium scorodonia, Dryopteris dilatata, Hyacinthoides non-scripta
SNT 1	2.00	2.06	W4b	B	Molinia caerulea, Calluna vulgaris
SWD 1	6.73	6.10	W8f	I	Mercurialis perennis, Allium ursinum, Deschampsia cespitosa, Corylus avellana
SWD 2	3.79	5.14	W16a	E	Rubus fruticosus, Deschampsia flexuosa, Dryopteris dilatata, Holcus mollis
SWD 3	4.03	4.92	W16a	E	Rubus fruticosus, Deschampsia flexuosa, Pteridium aquilinum
SWP 1	4.80	6.10	W10c	F	Rubus fruticosus, Dryopteris dilatata, Athyrium filix-femina
SWP 2	2.92	3.39	W16b	D	Pteridium aquilinum, Lonicera periclymenum Vaccinium myrtillus, Rubus fruticosus

Figure 5.3.1

Site details - Ellenberg indicator values, N.V.C. sub-community and dominant vegetation

CODE	ELLENBERG VALUES R	ELLENBERG VALUES N	NVC WOODLAND SUB-COMMUNITY	VISUALLY DOMINANT TYPE	MAIN FIELD LAYER SPECIES
SWP 3	3.42	4.35	W10a	D	Pteridium aquilinum, Dryopteris dilatata, Agrostis capillaris, Rubus fruticosus
TAY 1	2.44	3.45	W11d	G	Holcus mollis, Pteridium aquilinum, Oxalis acetosella, Agrostis stolonifera
TAY 2	7.18	8.57	W7a	J	Urtica dioica, Mercurialis perennis
THT 1	3.99	4.95	W10d	G	Holcus lanatus, Galium saxatile, Urtica dioica
THT 2	2.26	3.29	W16a	C	Deschampsia flexuosa, Stellaria media
THT 3	6.48	8.25	W8e	J	Urtica dioica, Galium aparine
THT 4	4.59	5.86	W10a	E	Rubus fruticosus, Dryopteris dilatata, Pteridium aquilinum
THT 5	4.96	6.19	W10a	E	Rubus fruticosus, Dryopteris dilatata
THT 6	3.14	3.52	W16a	D	Pteridium aquilinum, Holcus lanatus, Rubus fruticosus
WLD 1	3.01	2.91	W16a	D	Pteridium aquilinum, Molinia caerulea

Figure 5.4.1 Site: MOR2 - Culbin Forest, Moray
Vegetation type: A NVC: W18 mR-value =1.04

Figure 5.4.2 Site: SNT1 - Ariundle oakwood, Loch Sunart
Vegetation type: B NVC: W4 mR-value =2.00

Figure 5.4.3 **Site: KCD1 - Drumtochty Forest, Kincardine**
Vegetation type: C **NVC: W17** **mR-value =2.01**

Figure 5.4.4 **Site: NEW1 - New Forest**
Vegetation type: D **NVC: W16** **mR-value =3.03**

Figure 5.4.5 Site: THT4 - Thetford Forest
Vegetation type: E NVC: W10 mR-value =4.59

Figure 5.4.6 Site: BCH1 - Clashindarroch Forest, Buchan
Vegetation type: F NVC: W11 mR-value =3.93

Figure 5.4.7 **Site: TAY1 - Drummond Hill, Perthshire**
Vegetation type: G **NVC: W11** **mR-value =2.44**

Figure 5.4.8 **Site: NTH1 - Fineshade Forest, Northants**
Vegetation type: H **NVC: W10** **mR-value =5.35**

Figure 5.4.9 **Site: SWD1 - Whitwell Wood, Derbyshire**
Vegetation type: I **NVC: W8** **mR-value =6.73**

Figure 5.4.10 **Site: THT3 - Thetford Forest**
Vegetation type: J **NVC: W8** **mR-value =6.48**

6. SOIL NUTRIENT ANALYSIS - METHODOLOGY AND RESULTS

6.1 Literature review of soil analytical methods

There is an extensive literature on the chemical analysis of soil materials to determine nutrient levels, however this mainly reflects the experience and practice of workers studying tilled agricultural soils. The literature specific to the chemical analysis of forest soils is rather more limited. It has been generally accepted by many authors that forest soils present additional problems to the analyst, arising from (a) structural and spatial variability and (b) a lower "availability status" of some nutrients due to their incorporation in organic materials [humus] or in conservative mineral complexes. Classic overviews of forest soil science are provided by Lutz & Chandler (1949), Wilde (1958) and more recently by Pritchett & Fisher (1987), reflecting the strong contribution that workers in the United States have made to the discipline. The selection of determinands, for use in the development of a quantitative classification of forest soil nutrient regime, was considered by Kabzems & Klinka (1987) and Klinka, Wang & Kayahara (1994). Those suggested were pH, total carbon, total nitrogen, mineralisable nitrogen, extractable calcium, magnesium, potassium, phosphorus and sulphur. Standard laboratory methods for the determination of each of these have been provided by Allen (1989), Avery & Bascomb (1974), Black (ed.) (1965), Lavkulich (1981) and Page, Miller & Keeney (eds.) (1982). The practices of the IERM laboratory are based on experience-adapted versions of the techniques proposed by Allen (1989).

A determinand-by-determinand review will now be presented:-

pH

Soil reaction [pH] is the negative log of the hydrogen ion concentration. It can be estimated by the use of "Universal indicator", either in the form of a solution or an impregnated paper tab, applied to an aqueous suspension of the soil. However, such a method will only report to one significant figure at best. For the purposes of scientific investigation it is determined electro-chemically using a glass-electrode probe connected to an electronic potentiometer. This is now a standard methodology [see Allen (1989)]. The response of the instrument is pre-calibrated using buffered solutions of known pH. Precision of two significant figures can readily be achieved, and three with high-quality equipment. The latter is probably excessive for purposes of ecological investigation. The determination can be carried out in the field by direct application of the probe to the soil [on occasion "puddled" to improve contact] or by the creation of a suspension in water. However results have proved anecdotally unreliable. The determination is normally carried out in the laboratory in a suspension of the soil in either de-ionised water or alternatively in a dilute aqueous salt solution [usually 0.01M calcium or potassium chloride]. Certain authors have proposed the use of such a dilute salt solution as a means of limiting the influence of season of collection on the result obtained [Vezina (1965)]. The determination obtained in a salt solution was reported as lower than that in water, for a study in Quebec forest soils. The influence of the moisture status of the soil [fresh or air-dried] was not found to give rise to major differences in the pH determined. It must be accepted that any laboratory measure of pH may differ from the hypothetical "true" field value, the important factor is to achieve consistency within a suite of measurements [Small (1954)]. Other authors who have presented ideas on pH measurement are Gorham (1961) and Wilde (1954).

Nitrogen

The conventional determination of soil nitrogen is that obtained by the use of a catalysed wet oxidation of the soil [Kjeldahl digestion] with strong oxidising reagents. This is considered to give a measure of "total nitrogen", including that formerly incorporated in organic materials such as humus [Allen (1989)]. This was made somewhat less practically onerous by the development of the micro-Kjeldahl apparatus [Avery & Bascomb (1974)]. The drawback of this technique for ecological investigation is that the vast majority of the "total nitrogen" determined is not "plant-available". Indeed it is likely that the least fertile soils with a marked build-up of inert organic matter will yield the highest "total nitrogen" results. The "C/N ratio" - total carbon: total nitrogen - is used to compensate for this to some degree, and is still favoured by many soil scientists, especially in Continental Europe.

More recently, especially in North America, attention has centred on developing means of assessing "plant-available" nitrogen either instantaneously, or in terms of the soil's capacity to mineralise organic nitrogen into inorganic "available components" [nitrate-N and ammonium-N]. Keeney (1980) has produced a literature review on this subject. Two essential approaches have been proposed (a) a biological approach where the soil is incubated to allow microbial mineralisation processes to occur; and (b) a chemical approach where a moderate treatment is carried out to simulate the effect of this. In the first case the incubation can be conducted aerobically or anaerobically. An aerobic incubation has the potential to allow determination of both nitrate-N and ammonium-N separately, whereas an anaerobic incubation produces only ammonium-N [in place of both]. Anaerobic incubations are considered to be easier to conduct. Binkley & Hart (1989), Bremner (1965), Keeney & Bremner (1966), Keeney & Nelson (1982), Powers (1984) and Powers, Townsend & Laake (1978) compare various methods along these lines. For detailed consideration of incubation methods see Fyles, Fyles & Feller (1990), Powers (1980), Smith *et al* (1981), Stanford, Carter & Smith (1974) and Weetman, Prescott & Fournier (1992). Until very recently the balance of preference in the Pacific Northwest appeared to have tipped in favour of anaerobic incubation as witnessed by Klinka, Wang & Kayahara (1994), despite the loss of nitrate-N discrimination. However aerobic techniques have now been adopted [Klinka, pers. comm.]. Keeney & Bremner (1966b) extend the case for a chemical approach, whilst Binkley & Matson (1983) propose a field-based ion-exchange methodology. The use of incubation measures of mineralisable nitrogen has been seen to achieve considerable improvement as compared with the insight to be obtained from total nitrogen approaches. This has resulted in the adoption of mineralisable nitrogen as one of the main chemical discriminants of forest soil nutrient regime in British Columbia, for the Biogeoclimatic

Ecosystem Classification [Kabzems & Klinka (1987)]. Adoption of the measure in Continental Europe has been much more limited. However, it was applied successfully by Hawkes, Pyatt & White (1997) in their pilot study for the present investigation.

Analysis for the nitrate-N and ammonium-N components before or after incubation is by extraction with an aqueous solution of potassium chloride followed by automated colorimetric determination [Allen (1989)]. The soil should be stored under chilled conditions prior to these analyses, and should not be dried.

Phosphorus

A selection of plant available measures of soil phosphorus has been in use for agricultural purposes for some time. These rely on so-called "soft extractants" such as aqueous sodium bicarbonate [Olsen's reagent], aqueous ammonium acetate [acidified [Morgan's reagent] or otherwise], dilute aqueous acetic acid and dilute lactic acid [Egner's reagent]. Others have been proposed, even including pure water. They are discussed by texts such as Allen (1989) and by Williams (1952) and Williams (1967) of the Macaulay Institute, Aberdeen. These methods are generally considered adequate for agricultural soils where there is a pool of "readily-available" phosphorus derived from applied phosphate.

The record of these methods in forest soils has, however, been unsatisfactory. It is considered that the majority of phosphorus in forest soils is more tightly bound, although still, at least in part, available to trees through the action of mycorrhizal symbionts. It is found in both the organic fraction of the soil and in mineral complexes. The amount of this phosphorus extracted by the above methods is often erratic, and can be negligible. Malcolm (1970) reviews alternative approaches to the extraction of phosphorus from forest soils by the use of more aggressive reagents. The method proposed by Saunders & Williams (1955) involves the action of strong acids [e.g. aqua regia] on an ashed [dry oxidation] sample. Other methods use a wet oxidation technique analogous to the Kjeldahl method for nitrogen. These methods are thought to release all of the organic phosphorus, but may not obtain some of the most tightly bound minerally complexed element. Methods for determining "true total phosphorus" rely on the action of fluoride compounds, over a very short time interval, in platinum containers, and are thence difficult to apply to large sample batches. The relation of these various “strong extractions” for phosphorus to that which is plant available is difficult to establish in detail, but it is widely thought that the method after Saunders & Williams (1955) is unlikely to leave behind any plant-available phosphorus. The soil is usually dried prior to the conduct of these analyses.

Calcium, magnesium and potassium

The determination of the "plant-available" base cations does not pose the same difficulties as do those for nitrogen and phosphorus. The stocks of these elements are considered to be held in an "ion exchange complex" from which they can relatively easily be dislodged by the surplus supply of another cation with higher affinity. The usual choice is the ammonium ion in the form of ammonium acetate, but barium [as barium chloride], has been used by some workers. Allen (1989) and Avery & Bascomb (1974) present standard methods for the extraction. Determination now is mainly by atomic absorption spectro-photometry [David (1960)]. The selection of the pH for the extractant can be important, especially if calcareous soils are to be tested. Ideally the pH should match that of the soil, but this is not practical if a range of soils are to be tested with a consistent method. If neutral or calcareous soils are to be included, the extractant should not be made acidic, as it then will draw additional calcium into solution. A neutral pH for the extractant is prudent for a varied set of samples. These analyses may be carried out on fresh or air-dried soil, but the method should be held consistent for the set of samples.

Loss on ignition/ total carbon

Standard procedures are given by Allen (1989) and Avery & Bascomb (1974). Various oven temperatures and burn-times have been applied by different workers over the years. High temperature short burns [~850 degrees Celsius] were formerly used, but concern arose that calcium carbonate from calcareous soils might be destroyed by this, distorting the result. The trend has been to longer [overnight] combustion at 400 – 500 degrees Celsius to mitigate this risk. An estimate of the total carbon present can be made by dividing the loss-on-ignition result by a standard factor [usually 1.72 => carbon at 55% of combustibles]. If a precise determination of total carbon is required a wet oxidation technique can be employed [Allen (1989)].

Application in Great Britain

Most forest soil nutrient analytical work carried out in Great Britain to date has been aimed at prescribing appropriate supplemental nutrition for plantations. A relatively small body of work has been carried out from an ecological perspective. e.g. Malcolm (1970), Muir & Fraser (1939), Ovington (1953, 1956a, 1958a,b), Ovington & Madgwick (1957) and recently Hawkes, Pyatt & White (1997). Certain studies have been conducted where pH alone was measured in woodlands [e.g. Peterken (1993) and Rackham [pers. comm.]]. A recent focus of interest has been on the chemistry of the humus layer, either to illuminate its formation processes or to investigate the impact of certain tree harvesting methods on its mineralisation. The impact of the acid-base balance in litter on the development of humus form was discussed by Broadfoot & Pierre (1939) and Plice (1934) and has been taken up again much more recently by Howard & Howard (1990). Coulson, Davies & Lewis (1960) and Davies, Coulson & Lewis (1964) examined the significance of polyphenolic compounds on the rate of litter decomposition.

6.2 Description of analytical methods

It was decided that laboratory measures should be obtained for each soil layer of the "plant-availability" of the major soil nutrients, these being nitrogen [N], phosphorus [P], potassium [K], calcium [Ca] and magnesium [Mg]. In addition the pH value for each layer should be determined, together with the moisture content and loss-on-ignition. The methods applied for each determinand are set out below. These are largely the standard methods of the IERM laboratory as adapted from Allen (1989) by Mr. Andrew Gray.

pH

The determination of pH was carried out in the laboratory, using a standard glass-electrode pH meter manufactured by Russell [Glenrothes]. This was re-calibrated prior to each use with standard buffer solutions at pH4 and pH7. Field-use pH meters were not considered to be sufficiently reliable or precise for the purposes of this work.

For each layer a 10 g sample of re-mixed fine-earth in the field moist condition was mixed with 25 ml of de-ionised/ distilled water [1:2.5 w/v] in a clean plastic cup. This was agitated periodically for 15 minutes to achieve an equilibrium condition. A reading was then taken of the pH value one minute after insertion. A batch of 9 samples were tested on a given occasion, with the pH value for each being measured three times in rotation. The values obtained for each sample across the three readings were always similar. The simple average of the three readings was recorded to one decimal place.

The pH values were later re-measured in a 0.01M aqueous solution of calcium chloride, in response to advice [from Continental European soil scientists] that this measure was less affected by seasonal fluctuations in the field. The procedure was repeated as above with the exception that the number of re-measurements was reduced to two for each sample and the batch size increased to 15 samples.

Moisture content

The moisture content was determined by drying a 10g sample of re-mixed fine-earth, initially in the field-moist condition, in a laboratory oven for 24 hours at 80-90 degrees Celsius. The moisture loss was recorded and expressed as a percentage of the oven-dry mass of fine-earth.

Loss on ignition/ total carbon

The loss on ignition was determined, by combustion of a 10g sample of re-mixed fine-earth, in the field-moist condition, in a Carbolite [Sheffield] muffle-furnace, overnight, at 500 degrees Celsius. The moisture content determined above was deducted from the total loss to give the loss on ignition, where separate samples were used. Otherwise the tests were done successively on the same sample.

Nitrogen

It was decided that the supply of available nitrogen would be measured in terms of the mineral components, nitrate-N and ammonium-N. These were to be determined both before and after an aerobic incubation, in order to assess the potential of the soil to produce plant-available nitrogen, in both forms, under optimal conditions. It was expected that the post-incubation measure would display less volatility as a parameter of supply than the instantaneous quantity of mineral nitrogen available in the soil at any point in time. However the pre- and post-incubation measures proved strongly positively correlated [$r = 0.8$ for nitrate-N, $r = 0.6$ for ammonium-N]. Hence, only one of the measures may be required in future practice.

To minimise the extent to which any incubation of the sample could occur after removal from the field and prior to the commencement of the controlled incubation in the laboratory, field-moist analytical samples were stored under chilled conditions.

This was achieved in the first instance by placing the samples in insulated cool-boxes as soon as possible after collection, which were re-charged daily with frozen brine-packs. On return to the laboratory they were transferred to a cold store maintaining 1-4 degrees Celsius to await analysis.

The method of analysis consisted of an extraction with 1M aqueous potassium chloride solution followed by determination using an automated flow-injection colorimetric process. The extraction for each sample was carried out on duplicate 5 g sub-samples of re-mixed fine earth in the field-moist condition. Each sub-sample was placed in a 150ml capacity brown glass bottle to which was added 100 ml of the solution above. The bottles were then closed and mechanically shaken for 2 hours in a Gallenkamp orbital incubator at room temperature. After completion of this period the bottles were removed and the extract allowed to settle for 1/2 to 1 hour. An aliquot of 15ml was then pipetted-off and centrifuged for 15 minutes at 4-5000 rpm. The clear aliquot was decanted into a clean 25 ml sample tube, and held in cold storage to await determination. Ammonium-N and nitrate-N were then determined colorimetrically using a flow-injection auto-analyser. Some samples were determined in the IERM laboratory using a Perstorp Analytical Enviro-flow system, whilst others were determined on contract by the Scottish Agricultural College Central Analytical Laboratory, using an equivalent method.

The method for incubation was as follows. A further set of duplicate 5 g sub-samples for each soil sample were taken. These were placed in separate 25 ml clean sample tubes. Each sample was irrigated at the outset to achieve a consistent moisture status independent of the field condition. These were stoppered to restrict moisture loss, and placed in a Gallenkamp cabinet incubator for 28 days at 30 degrees Celsius. The incubations were each inspected twice weekly. At each inspection the cap was removed to vent the headspace and irrigation was performed with de-ionised/ distilled water as required to maintain an aerobic but moist condition. At the end of the 28 days the incubated sub-samples were analysed as above. Removal from the sample tubes was carried out by washing the soil into the extraction jars with the extractant itself in a wash-bottle.

Batches of up to 18 samples [36 extractions] were processed on a single day, with blank samples of extractant for each batch being retained. The background level of nitrate-N or ammonium-N in the blank was subtracted from those determined for the extractions. An average of the duplicate results for each sample was recorded. Correspondence of the duplicates was very satisfactory overall, although very low values tended to be relatively more variable. Results were calculated in terms of both oven-dry mass fractions and nutrient quantities per hectare in the top 50 cm. The post-incubation measure was taken on its own account, without subtraction of the "available" (pre-incubation) measure.

Initially it had been intended, in addition, to measure total nitrogen by a Kjeldahl digestion method. However it was felt that this was no longer justified given the highly satisfactory results obtained for the available and mineralisable nitrogen components above. A pilot study had shown that total nitrogen did not emerge as a significant soil variable in determining ground vegetation species composition as compared with the mineral nitrogen components, which were highly significant [principally nitrate-N][Hawkes, Pyatt & White (1997)]

Phosphorus

In keeping with the decision to measure the "plant-available" levels of the main soil nutrients, an attempt was made to do this for phosphorus. The method of analysis consisted of an extraction with 1M aqueous ammonium acetate solution [at pH7] followed by determination using an automated flow-injection colorimetric process. The extraction for each sample was carried out on duplicate 5 g sub-samples of re-mixed fine earth in the field-moist condition. Each sub-sample was placed in a 150 ml capacity brown glass bottle to which was added 100 ml of the solution above. The bottles were then closed and mechanically shaken for 2 hours in a Gallenkamp orbital incubator at room temperature. After completion of this period the bottles were removed and the extract allowed to settle out for 1/2 to 1 hour. An aliquot of 15 ml was then pipetted-off and centrifuged for 15 minutes at 4-5000 rpm. The clear aliquot was decanted into a clean 25 ml sample tube, and held in cold storage to await determination. Phosphorus was then determined colorimetrically using a flow-injection auto-analyser. Some samples were determined in the IERM laboratory using a Perstorp Analytical Enviro-flow system, whilst others were determined on contract by the Scottish Agricultural College Central Analytical Laboratory, using an equivalent method.

The results obtained proved of limited value. The amounts of phosphorus extracted were on the whole very low, and many were so low as to be irresolvable from background fluctuations in the blank solution. As a consequence, over half the results were reported as zero. Those samples which did record a non-zero result were subject to considerable relative variation between the duplicates. It was therefore decided that these results did not meet their objective and that an alternative measure of phosphorus should be obtained. Advice suggested that alternative "plant available" measures of the nutrient might also yield disappointing results when applied to forest soil samples, where much of the phosphorus present is either in an organic form or tightly bound in mineral complexes.

Hence it was decided to obtain a measure approximating to total phosphorus. This analysis was conducted entirely by the Scottish Agricultural College Central Analytical Laboratory, using a digestion in aqua regia. The results obtained were much more satisfactory. Once again the results were expressed both as oven-dry mass fractions and as nutrient quantities per hectare.

Potassium, magnesium and calcium

The extractable quantity of these elements was determined on the same extract in 1M ammonium acetate [pH 7] as described above. The determinations were carried out by atomic absorption spectro-photometry using a Unicam 919 "Solar System" spectro-photometer in the IERM laboratory. Again background levels for each element in the blank extractant were deducted. Correspondence of duplicates for the cation determinations was excellent. Once again the results were expressed both as oven-dry mass fractions and as nutrient quantities per hectare.

Other possible analyses

Initially, it had been considered that it might be desirable to measure the cation exchange capacity [C.E.C.] of each soil to allow the base saturation to be calculated. Some soil scientists believe this measure to convey extra ecologically significant information over and above that to be obtained from a joint consideration of the supplies of calcium, magnesium and potassium and of the pH [a measure of hydrogen ion concentration]. However, the procedure required to measure the cation exchange capacity proved to be too time consuming to perform for the number of samples involved within the project timetable. It is considered that the measures made of base cations and of pH will provide sufficient insight into soil base status for the purpose of this work.

In tropical soil nutrient studies it is common to measure the aluminium status of the soil [usually in relation to either the C.E.C. or to the total supply of the base cations]. This is due to the plant-toxic effects which high aluminium concentrations can produce in strongly acidic soils. However, this has not normally been considered significant in British soil conditions, and so was not pursued within this study.

Analyses for sodium and sulphur were considered, but were not considered a priority given the time and resource constraints applying.

6.3 Results of soil analyses

The soil chemical analysis results for the soil profile to 50cm depth are given in Figure 6.3.1 [spatial basis]. Detailed layer results [spatial and oven-dry mass-fraction bases] are contained in Appendix 4.

pH

For pH in water, values from **2.8 to 7.3** were obtained, with many samples having pH values in the range 3.5 to 4.5. Surface layers consistently had lower pH values than those from deeper in the soil profile.

For pH in calcium chloride, the results were found to be rather similar to those determined in water, although some individual samples did exhibit modest differentials in either sense. Values from **2.7 to 7.1** were obtained, with the same general distribution as noted above. No evidence was found to support previous reports of either large overall differences between the two measures or of a constant differential of ~0.7 units.

It was noted that a large number of the samples displayed pH values below 4. There has been considerable comment recently that forest soil pH values recorded in recent years appear to show an overall decline of up to one pH unit from those obtained in older measurements, when values of 4 to 5 were more normal. There seems little consensus as to whether this is a real effect caused by deposition of acidifying pollutants or an artefact of improved instrumental technology. It must be stated that a measurement taken under an established forest canopy should not be compared with a pre-establishment value taken in the open, as acidification by litter-fall and cation uptake is likely to have occurred in the interim.

Moisture content

A range of moisture contents from to **<u>0.7% to 384.5%</u>** was recorded [based on oven-dry fine-earth]. High values were obtained for organic layers, and low values for pure sands, as would be expected. As all sampling was carried out in the summer months, it is expected that some soils will be displaying their driest state.

Loss on ignition

Values recorded for loss on ignition ranged from **<u>98 to 532 Mg/ha</u>** in the top 50 cm of soil **[<u>Mean 252 Mg/ha</u>].** The loss on ignition can be used to estimate the total carbon present by assuming a standard carbon content of the combustibles. This is usually taken as 55%, although it does vary somewhat for different sample types. For this work the loss on ignition value was used unconverted. It was not considered that the significance of total carbon as a soil variable was sufficient to justify the measurement of the quantity directly by a wet oxidation technique.

Nitrogen

Most soils showed an increase in both nitrate-N and ammonium-N after the incubation, although a small proportion appeared to show conversion of ammonium-N to nitrate-N. The results displayed the following ranges for the top 50 cm of soil:-

Available nitrate-N	**<u>0 to 274 kg/ha</u>**	**<u>[Mean 40 kg/ha]</u>**
Mineralisable nitrate-N	**<u>0 to 311 kg/ha</u>**	**<u>[Mean 69 kg/ha]</u>**
Available ammonium-N	**<u>0 to 136 kg/ha</u>**	**<u>[Mean 33 kg/ha]</u>**
Mineralisable ammonium-N	**<u>0 to 364 kg/ha</u>**	**<u>[Mean 94 kg/ha]</u>**

Most soils displaying high nitrate-N had low ammonium-N (although not without exception) and *vice versa.* Some soils manifested very low levels of both, and others moderate levels of both. The quantity of nitrate-N appeared to be related to pH and to that of other nutrients in a positive sense, whereas this did not seem to be the case for ammonium-N. Some otherwise infertile soils with a "mor" humus type produced considerable amounts of ammonium-N.

Phosphorus

Values recorded for total phosphorus ranged from **136 to 3640 kg/ha** in the top 50cm of soil **[Mean 1350 kg/ha].** The values for phosphorus appeared to be positively related to the level of pH and of the other soil nutrients, with the exception of ammonium-N.

Calcium, magnesium and potassium

The value ranges recorded for the three cations for the top 50 cm of soil were as follows:-

Calcium	**45 to 40990 kg/ha**	**[Mean 4457 kg/ha]**
Magnesium	**39 to 3513 kg/ha**	**[Mean 389 kg/ha]**
Potassium	**56 to 1328 kg/ha**	**[Mean 254 kg/ha]**

The values for the cations appeared to be positively related to those for pH and the other soil nutrients with the exception of ammonium-N. This was less clearly the case for the potassium values. Several soils were sampled with large supplies of free calcium [>10000 kg/ha] - these were usually profiles with visible chalk or limestone fragments, or calcareous littoral sand. The calcium values for these samples should be considered lower bounds due to instrumental response saturation. One soil was sampled with a high magnesium supply due its having Permian magnesian limestone in the profile [Plot SWD1 - Whitwell Wood, Sherwood].

Key to Figure 6.3.1

pH [H_2O]	pH determined in water for top, middle & bottom soil layers
pH [$CaCl_2$]	pH determined in calcium chloride for top, middle & bottom soil layers
EXT Ca	Calcium extractable in 1M ammonium acetate pH7
EXT Mg	Magnesium extractable in 1M ammonium acetate pH7
EXT K	Potassium extractable in 1M ammonium acetate pH7
TOTAL P	Phosphorus determined in aqua regia digest
AV NO_3:N	NO_3-nitrogen extractable in 1M potassium chloride pre-incubation
MIN NO_3:N	NO_3-nitrogen extractable in 1M potassium chloride post-incubation
AV NH_4:N	NH_4-nitrogen extractable in 1M potassium chloride pre-incubation
MIN NH_4:N	NH_4-nitrogen extractable in 1M potassium chloride post-incubation
L.O.I.	Loss-on-ignition at 500°C

Figure 6.3.1

Summary soil analytical data [aggregated to 50cm depth]

CODE	FOREST/ WOOD	pH [H2O] [TOP]	pH [H2O] [MIDDLE]	pH [H2O] [BOTTOM]	pH [CaCl2] [TOP]	pH [CaCl2] [MIDDLE]	pH [CaCl2] [BOTTOM]	EXT Ca kg/ha	EXT Mg kg/ha	EXT K kg/ha	TOTAL P kg/ha	AV NO3:N kg/ha	MIN NO3:N kg/ha	AV NH4:N kg/ha	MIN NH4:N kg/ ha
ABF 1	TENTSMUIR	4.1	5.7	6.7	3.4	5.4	6.4	3740	354	76	2306.3	9.6	4.5	5.9	89.1
ABF 2	LOCH ARD	3.7	3.9	4.1	3.0	3.8	4.1	115	121	61	907.4	26.6	0.8	22.3	119.7
AE 1	AE	3.4	3.9	4.0	3.3	3.6	3.8	331	137	137	1824.0	31.5	62.5	18.3	105.5
AE 2	MABIE	4.1	4.5	4.8	3.9	4.3	4.6	1573	167	111	1573.6	15.8	22.8	12.4	69.7
AWE 1	KILMICHAEL	3.3	3.8	4.1	3.2	3.8	4.0	751	209	122	1167.8	24.4	54.8	19.8	57.6
BAL 1	BALMORAL	3.8	3.9	4.0	3.5	4.1	4.3	392	170	155	700.2	7.5	15.1	11.0	67.2
BCH 1	CLASHINDARROCH	3.6	3.7	3.9	4.0	4.0	4.2	1165	761	278	2759.8	76.3	76.7	0.9	64.7
BCH 2	LESCHANGIE	3.3	3.1	3.3	3.1	3.5	3.8	155	97	179	925.7	34.3	78.7	36.4	74.0
CER 1	CWM YSTWYTH	3.6	3.6	3.8	3.2	3.7	4.0	74	39	89	1033.8	15.4	42.4	29.4	79.6
CHT 1	QUEEN & COLLEGE	3.6	3.6	6.9	3.9	4.1	6.9	24322	339	238	1367.0	56.7	129.1	19.2	43.4
DEN 1	DEAN	3.5	3.7	3.9	3.3	3.5	3.6	337	96	247	1060.0	43.5	119.5	9.6	26.6
DEN 2	DEAN	2.8	3.0	3.1	2.9	3.2	3.7	325	82	192	1073.6	34.2	48.2	26.3	79.0
DEN 3	DEAN	3.0	3.3	3.4	3.4	3.6	3.7	222	75	306	1046.3	56.7	101.4	45.8	81.4
DEN 4	DEAN	3.5	3.7	3.7	3.6	3.7	3.6	1470	657	511	1247.5	36.8	80.7	44.4	76.4
DEN 5	DYMOCK	3.5	3.5	3.6	3.5	3.4	3.5	526	877	504	756.4	1.2	0.0	64.1	121.6
DEN 6	DEAN	3.0	3.3	3.3	3.4	3.4	3.6	197	117	209	729.8	34.4	85.0	15.9	32.7
DEN 7	KINGS WOOD WARR	3.1	3.1	3.4	3.0	2.9	3.3	841	136	125	373.9	29.0	24.8	57.4	116.8
DOW 1	ALICE HOLT	3.9	4.2	4.2	3.1	3.5	3.6	8055	2212	787	1522.5	8.0	32.4	61.4	128.9
DOW 2	MICHELDEVER	3.5	3.8	4.0	3.3	3.5	3.8	4177	1022	312	953.2	36.0	111.3	40.1	87.0
DOW 3	BRAMSHILL	3.1	3.2	3.6	3.0	2.9	3.5	535	165	196	394.0	3.3	2.2	80.3	135.3
DOW 4	LIPHOOK	3.4	3.8	3.8	2.9	2.6	2.9	549	93	159	367.7	3.9	3.7	25.0	83.8
DOW 5	BLACK WOOD	5.4	5.3	7.3	5.2	4.8	6.8	24658	924	305	2228.0	102.6	311.1	14.1	9.5
DOW 6	HURSLEY	4.2	4.3	4.6	3.6	3.5	3.8	6976	2078	569	1047.9	34.1	84.0	45.8	146.1
DST 1	BLANDFORD	4.4	4.6	4.6	4.9	4.8	4.7	5617	302	212	1976.6	102.5	245.2	0.0	2.2
GTN 1	DINNET OAKWOOD	3.8	3.7	3.8	3.7	3.8	4.1	217	86	145	793.9	5.5	18.9	25.8	97.7
INV 1	CULBOKIE	3.4	3.8	4.3	3.2	3.4	3.9	560	156	210	399.0	0.4	7.5	2.1	44.6
INV 2	CULLODEN	3.7	3.7	3.7	3.6	3.6	3.9	312	128	167	609.8	0.2	9.3	16.2	80.1

Figure 6.3.1
Summary soil analytical data [aggregated to 50cm depth]

CODE	FOREST/ WOOD	pH [H2O] [TOP]	pH [H2O] [MIDDLE]	pH [H2O] [BOTTOM]	pH [CaCl2] [TOP]	pH [CaCl2] [MIDDLE]	pH [CaCl2] [BOTTOM]	EXT Ca kg/ha	EXT Mg kg/ha	EXT K kg/ha	TOTAL P kg/ha	AV NO3:N kg/ha	MIN NO3:N kg/ha	AV NH4:N kg/ha	MIN NH4:N kg/ ha	L.O.I. Mg/ha
KCD 1	DRUMTOCHTY	3.5	3.4	3.4	3.1	3.3	3.9	95	115	211	979.7	25.4	12.3	86.0	167.0	278
KCD 2	DRUMTOCHTY	3.1	3.3	3.4	2.8	3.1	3.8	75	125	152	756.5	14.2	19.7	71.0	155.3	313
KIN 1	KNAPDALE	3.3	3.6	3.9	3.0	3.2	3.6	151	203	93	1116.8	3.6	18.3	59.5	220.3	532
KIN 2	KNAPDALE	3.3	3.6	3.8	3.1	3.5	3.8	152	168	119	2159.8	3.9	17.6	13.5	52.5	380
LAK 1	THORNTHWAITE	3.4	3.4	3.6	3.6	3.7	3.9	469	105	162	3409.4	43.7	110.7	32.8	86.0	321
LAK 2	GRIZEDALE	3.0	3.4	3.6	3.5	3.9	4.1	234	49	134	1247.8	51.6	247.7	16.2	50.6	221
LAK 3	DODD	3.5	3.6	3.7	3.3	3.6	3.9	209	69	117	1742.2	18.5	50.7	0.7	11.1	211
LCH 1	LEANACHAN	3.7	3.7	3.8	3.3	3.8	4.0	214	164	88	708.5	17.7	23.8	28.1	88.6	365
LND 1	PEMBREY	4.6	5.4	5.7	5.6	6.6	6.9	39239	609	220	1674.9	0.0	18.7	14.1	31.8	99
LND 2	PEMBREY	5.3	5.5	5.7	5.6	6.7	7.1	36702	646	254	1695.8	16.4	82.1	5.7	0.0	164
LOT 1	GLENTRESS	3.7	4.4	4.8	3.4	4.1	4.5	5642	902	205	2011.4	19.5	45.0	50.5	143.9	311
LOT 2	GLENTRESS	3.1	3.5	3.7	3.0	3.5	3.7	171	79	178	1289.0	25.9	49.8	16.3	71.0	231
LWT 1	GYWDR	3.2	3.0	N/A	2.9	2.8	N/A	125	86	56	136.4	3.8	8.7	37.1	71.7	153
LWT 2	GWYDR	3.1	3.5	3.7	3.3	3.9	4.1	45	47	81	2097.9	30.5	64.8	15.6	39.6	307
MCH 1	WYRE	3.7	3.9	4.3	3.8	3.7	4.0	944	297	355	517.1	70.3	76.1	27.0	205.3	159
MCH 2	WIGMORE ROLLS	4.5	5.5	5.5	4.7	5.1	5.2	16566	1351	544	2501.3	136.5	167.5	89.2	363.7	397
MID 1	CANNOCK	3.2	3.5	3.6	3.1	3.4	3.7	1204	119	228	559.8	44.0	27.6	53.5	221.5	281
MOR 1	MONAUGHTY	3.6	3.5	3.6	3.2	3.4	3.7	198	104	123	644.6	17.4	18.9	15.8	105.3	236
MOR 2	CULBIN	3.2	3.7	4.1	2.8	3.4	4.1	317	96	113	330.2	10.6	12.4	0.0	53.7	98
MOR 3	TEINDLAND	3.4	3.5	3.8	2.8	2.9	3.6	49	83	129	370.1	19.7	1.7	0.0	57.2	329
NEW 1	NEW	3.8	3.6	3.7	3.2	3.2	3.5	3374	312	913	533.0	5.0	0.2	45.0	104.0	323
NTH 1	FINESHADE	3.4	4.1	5.1	3.7	4.1	5.4	6607	376	204	2274.9	108.8	87.9	50.9	287.9	293
NTH 2	APETHORPE	4.7	6.4	7.2	5.0	6.1	6.9	40990	1183	1328	3268.1	274.2	256.8	5.3	180.1	437
NYM 1	DALBY	3.2	4.6	6.7	3.6	4.6	6.5	13260	576	349	1680.9	77.0	83.8	0.5	32.4	224

Figure 6.3.1

Summary soil analytical data [aggregated to 50cm depth]

CODE	FOREST/ WOOD	pH [H2O] [TOP]	pH [H2O] [MIDDLE]	pH [H2O] [BOTTOM]	pH [CaCl2] [TOP]	pH [CaCl2] [MIDDLE]	pH [CaCl2] [BOTTOM]	EXT Ca kg/ha	EXT Mg kg/ha	EXT K kg/ha	TOTAL P kg/ha	AV NO3:N kg/ha	MIN NO3:N kg/ha	AV NH4:N kg/ha	MIN NH4:N kg/ ha	L.O.I. Mg/ha
SEA 1	CURR	3.4	3.5	3.6	2.9	3.5	4.1	258	166	131	774.6	1.8	5.5	1.7	38.7	386
SEW 1	CWMCARN	3.3	3.2	3.6	2.8	3.0	3.6	135	89	128	1057.3	10.0	14.6	50.9	90.7	276
SFD 1	STOCKSFIELD	3.3	3.5	3.8	3.3	3.5	3.7	1015	393	438	1488.3	64.4	92.5	27.1	54.8	345
SNT 1	ARIUNDLE	3.9	3.8	3.9	3.5	3.9	4.0	281	212	164	911.2	4.6	28.5	53.1	182.0	436
SWD 1	WHITWELL	5.9	6.3	7.0	6.2	6.5	6.8	9639	3513	861	1719.4	191.0	296.6	2.4	180.2	282
SWD 2	SHERWOOD	3.1	3.3	3.3	3.1	3.7	3.9	280	80	153	1699.4	15.8	12.9	12.3	33.1	175
SWD 3	SHERWOOD	3.0	3.1	3.4	3.0	3.4	3.8	368	82	167	819.7	22.1	20.3	30.5	80.5	181
SWP 1	WELL, LISKEARD	3.3	3.8	4.5	3.6	4.0	4.5	766	141	185	2510.7	57.9	145.3	10.1	30.4	273
SWP 2	ABBEYFORD	3.7	3.8	3.8	3.2	3.6	4.0	406	133	318	1035.3	24.2	8.3	93.1	208.5	260
SWP 3	BRENDON	3.3	3.5	4.0	3.1	3.7	4.0	466	79	281	1092.6	47.0	58.4	130.2	206.1	186
TAY 1	DRUMMOND HILL	3.8	3.7	4.1	3.6	3.9	4.1	91	114	97	2083.9	46.5	89.0	12.6	68.2	167
TAY 2	KINFAUNS	5.1	5.3	5.6	5.0	5.2	5.3	13890	1710	628	3639.8	141.6	293.3	1.1	12.0	239
THT 1	THETFORD	3.7	4.5	5.8	3.0	3.9	5.7	4208	105	139	1482.2	45.0	106.8	43.5	65.3	182
THT 2	THETFORD	3.3	3.1	3.7	2.9	2.8	3.4	832	72	146	2101.2	9.8	4.1	26.1	64.9	266
THT 3	THETFORD	4.6	6.5	7.1	4.6	6.4	6.8	19975	483	272	2529.7	129.2	271.7	0.0	5.1	181
THT 4	THETFORD	3.3	3.6	3.7	3.0	3.0	3.5	367	79	137	1274.7	17.1	26.2	85.3	74.6	148
THT 5	THETFORD	3.1	3.4	3.6	2.8	3.0	3.4	426	84	127	1024.4	22.9	23.8	88.7	73.1	154
THT 6	THETFORD	3.3	3.3	3.4	2.9	2.8	3.1	532	83	196	2033.4	39.0	77.2	135.5	88.6	186
WLD 1	BEDGEBURY	3.2	3.3	3.5	2.8	2.7	3.2	2826	116	269	359.3	6.3	0.0	33.6	92.6	419

7. STATISTICAL ANALYSIS - METHODOLOGY AND RESULTS

7.1 Literature review of ecological multivariate statistical analysis methods

The literature regarding the statistical analysis of ecological datasets has expanded dramatically over the past two decades. This reflects two main trends (a) the shift from a dominantly phyto-sociological view of vegetation science, to a functional, factorial approach [see Chapter 5] and (b) the rapid increase in the availability and convenience of computer-based techniques.

Prior to the advent of the mainframe computer in the 1960's, it was essentially impractical to carry out complex statistical analysis of multi-variate datasets such as vegetation quadrat data. The abundance of particular species could be related to individual measured environmental variables by the use of pre-selected functional models [e.g. linear, polynomial or uni-modal]. This was valuable in allowing the derivation of "indicator values" for each species for a set of environmental variables. It also illuminated the fact that species abundance usually displays a uni-modal relation to environmental variables. However, it does not allow the structure within multi-variate datasets to be exposed:- for example the degree of clustering of samples or the existence of major continuous gradients of variation.

With the arrival of suitable computer techniques in the 1960's, it became possible to consider whole multi-variate datasets simultaneously. This was applied not only in vegetation ecology, but also in fields such as archaeology, palynology, psychology and economics. In vegetation ecology, the earlier approaches usually considered the vegetation quadrat data alone, without the explicit involvement of measured environmental variables. These approaches took two forms (a) cluster analysis and (h) indirect gradient analysis.

The cluster analysis techniques were of particular relevance to ecologists working within a phyto-sociological framework. Their intention was to provide a statistically validated basis for the division of a set of sites, which had been subjected to vegetation sampling, into discrete ecologically-based groupings or "clusters". This was carried out by an iterative routine using the occurrence and abundance data only, but now considering the co-variation of species. If desired, the groups identified could then be considered in the light of observed or measured environmental features of the sites, which might explain the structure discerned. This technique was embodied in computer routines such as "CLUSTAN" [CLUSTer ANalysis]. The cluster analysis approach could be inverted to produce groupings of species occurring on the same sites within a dataset. If these site groupings could be assigned some ecological meaning, the species clusters could become "indicator species groups" with the benefit of statistical validity. This method is now most commonly applied through the computer routine "TWINSPAN" [TWo-way INdicator SPecies ANalysis]. The indicator species groups produced by a cluster analysis approach are thus, by definition, indicative of site membership of a discrete class of sites, rather than of site position on a variate continuum.

Ecologists approaching the data from a functional viewpoint preferred a class of statistical techniques collectively know as "factor analyses". Factor analysis techniques all have in common that they attempt to isolate the major linear gradients of variation within multi-variate datasets. Species abundance is assumed to depend upon these gradients according to a pre-selected model [usually linear or uni-modal]. Early modes of factor analysis in vegetation ecology were applied to the vegetation data alone without the inclusion of explicit environmental variables, and hence were termed "indirect gradient analyses". If the assumption is of linear dependence, the technique is known as "Principal Components Analysis" [PCA]. If the assumption is of uni-modal dependence the technique is known as "Correspondence Analysis" [CA]. It was evident from earlier work that species response to environmental gradients such as those in climate, soil moisture or soil nutrients was uni-modal rather than linear in most conditions, especially where competition between species applied. Hence CA became the preferred technique for this purpose. [PCA is primarily used for investigating co-variation between sets of measured environmental variables, where the model of linear inter-dependence is *prima facie* a more reasonable one]. Both techniques operate by identifying the first axis of variation as that which captures the greatest proportion of the variation in vegetation species composition. The second and successive axes are those which explain the greatest proportion of residual variation, subject to a condition of mutual orthogonality. Both sites and species can then be given ordinated "scores" on each axis. Whether the axes have any apparent ecological significance must then be explored. A weakness of such "unconstrained" factor analysis techniques is that they often produce axes that are not intuitively significant. Workers using CA discovered that, on occasion, the second and subsequent axes retain an undesirable higher-order polynomial relation with the first axis. This is known as the "arch effect", because it emerges as a polynomial dependence of the site and species scores on one axis upon those on another [if this is of a second order form, the arch appears on the scoring diagram for the two axes concerned]. Various methods have been proposed to "strip out" the arch effect by "de-trending" the analysis, giving rise to "De-trended Correspondence Analysis" [DCA], which is now preferred to basic CA. This is available within the computer routine "DECORANA" [DE-trended CORrespondence ANAlysis], where the de-trending is carried out by segmentation. The routine-set "CANOCO" [see below] offers the more elegant polynomial methods of de-trending. De-trending has not been found to be possible for PCA, due to reflection ["horseshoe" form] of the "arch".

The routines TWINSPAN [Hill (1979)] and DECORANA [Hill & Gauch (1980)] are supplied as a package entitled "VESPAN" [VEgetation SPecies ANalysis], by the Unit of Vegetation Science, University of Lancaster.

Many individual studies using these earlier techniques have been published, but useful reviews of their application are provided by Digby & Kempton (1987), Jongman, ter Braak & van Tongeren (1987), Ludwig & Reynolds (1988) and Pielou (1984). Hawkes, Pyatt & White (1997) illustrate the use of Principal Components Analysis in the pilot work for the present study.

The drawback of indirect gradient factor analysis techniques such as CA and DCA is that they may produce axes without apparent ecological relevance. As most investigations using the techniques are seeking to characterise the species composition of the vegetation in relation to measured environmental variables, a number of so-called "direct gradient analysis" or "constrained factor analysis" techniques have been developed. These share the feature that they impose an additional condition on the selection of the primary and subsequent axes, namely that they should be expressible as linear combinations of the environmental variables included. These axes are then termed "canonical" axes. When applied to Correspondence Analysis, this extra condition leads to "Canonical Correspondence Analysis" [CCA]. It is possible to carry out "De-trended Canonical Correspondence Analysis" [DCCA], but the first axis is not affected by this. Both CCA and DCCA can conveniently be carried out with the computer routine-set "CANOCO" [CANOnical COmmunity] [ter Braak (1991)], supplied by Campus Software, Wageningen, Netherlands. It is also possible to carry out a canonical version of Principal Components Analysis, known as "Redundancy Analysis" [RDA], but this is not usually applied by ecologists because of the linear species response model implicit within it [see comments relating to PCA above]. The use of CCA instead of CA may result in a lower proportion of the variation in the vegetation species composition data being explained, as variation due to unmeasured factors is essentially filtered-out by the additional constraint on axis selection. However those axes that are produced by CCA can be immediately related to the environmental gradients of interest to the investigator.

For full treatment of the methodology of CCA and DCCA see Jongman, ter Braak & van Tongeren (1987) and ter Braak (1986, 1987). A summary drawn from these sources is provided by Reyment & Joreskog (1993). Gegout & Houllier (1993) describe the use of the techniques for forest site classification in north-eastern France.

A subsidiary technique, which has been shown to be of use in the analysis of vegetation-environment datasets, is known as "Canonical Correlation Analysis"

[COR]. This technique was developed before the advent of CCA [see above]. Whereas CCA uses a combination of correspondence analysis on the vegetation species data and multiple linear regression on the environmental data, COR applies the latter technique to both parts of the dataset. This results in the production of a set of mutually orthogonal axes, which are forced to be expressible as both (a) a linear combination of the species abundances and (b) a linear combination of the environmental variables. This can be seen as rather a rigorous condition. In particular it requires that there are fewer species than sites within the data, a condition that can rarely be met in ecological research contexts. However if the vegetation data can be re-expressed in terms of descriptive indices such as weighted-mean site indicator values, this obstacle can be overcome.

COR analysis receives brief descriptions from Digby & Kempton (1987), Ludwig & Reynolds (1988) and Reyment & Joreskog (1993). Once again the best source is Jongman, ter Braak & van Tongeren (1987).

PCA and COR computer routines are contained within the routine-set "GENSTAT 5" produced by Rothamsted Experimental Station, Harpenden.

7.2 **Description of statistical methods employed**

In selecting the suite of multi-variate statistical techniques to employ it was important to keep in mind the objectives of analysis as described at the conclusion of Chapter 2. Namely (a) to identify the soil nutrient variables explaining the majority of the variation between sites *per se* and (b) to identify the soil nutrient variables explaining the greatest variation in vegetation species composition between the sites. In the former case the ability of the ground vegetation to predict the status of these variables would require to be demonstrated. In the latter case this should be implicit in the relationship identified.

As a result of the sampling and analytical work the following information was available for use in the analyses:- (a) vegetation species abundance data and (b) soil chemical data. In addition, the preliminary processing of the vegetation data had produced abundance-weighted site mean Ellenberg indicator values mR and mN [see Chapter 5]. The soil physical measures, including moisture content and bulk density, were not used explicitly in the statistical analyses, as the stated aim was to investigate the ecological influence of soil chemical variables. However they are implicitly considered due to their influence on the supply of soil nutrients on a per hectare basis. Soil moisture content and bulk density also guide the assignment of soil moisture classes as discussed in Chapter 2.

Principal Components Analysis

In pursuit of the first objective above, it was decided to carry out a Principal Components Analysis on the soil chemical data alone. The aim was to identify those soil chemical variables which best describe the variation between the soils of the 70 sites studied. This followed the example of the pilot study [Hawkes, Pyatt & White (1997)], which adopted this approach for a sample of 20 sites. The analysis was carried out using the computer package "GENSTAT 5" [Rothamsted Experimental Station, Harpenden].

The routine was run twice using the two alternative sets of measurements of soil pH (a) in water and (b) in 0.01M calcium chloride solution. It was decided to use a standard logarithmic [base 10] data transformation, as the untransformed value ranges of the chemical variables differed markedly [for example extractable calcium ranged through five orders of magnitude]. The pH data were already in logarithmic form by definition, and so did not need to be transformed in this way. The analyses were performed on the "sums of the squares of the products matrix" as opposed to the correlation matrix. This can have the effect of emphasising the importance of those variables with the greatest range of values [James & McCulloch (1990)]. However, this significance of this will be lessened, given that the data have been transformed by logarithms as described. The use of this matrix also has the advantage of permitting the application of a "test of quality" routine to the axes generated, which is not possible when the correlation matrix is employed.

Hawkes, Pyatt & White (1997) explored the ability of the vegetation species composition to predict the site score on their first Principal Component. This was carried out using the abundance-weighted site mean Ellenberg indicator values mR and mN in the linear combination mR + mN, with which a strong correlation was demonstrated. It was decided to extend this approach to the larger dataset produced by the present study. In the pilot work it was reported that measures of pH and of available and mineralisable nitrate-N had emerged as the most important descriptors of soil variation within Principal Components Analysis.

Canonical Correlation Analysis and Canonical Correspondence Analysis

In pursuit of the second objective above, it was decided to carry out analyses on the vegetation species data and the soil chemical data together. This was performed in two ways:- (a) a canonical correlation analysis [COR] using the soil chemical data and the site mean Ellenberg indicator values and (b) a canonical correspondence analysis [CCA] using the soil chemical data and the vegetation species abundance data. It was expected that these two techniques would produce alternative ordinations of the sites, which would allow the effectiveness of using Ellenberg indicator values to be compared with the use of internally produced indicator values from the study data. This was considered an important verification process given that Ellenberg values were originally developed for use in Central European conditions.

The COR analysis was performed twice using the two sets of pH data, in a similar way to PCA above. It was again run using the GENSTAT 5 package. The soil chemical data were again used in a logarithmic form for the reason stated above. It was not considered necessary to transform the Ellenberg site indicator values mR and mN, as they are on an integer scale from 1 to 9.

The CCA analysis was performed once on the full set of data, including both pH value-sets. It was run using the "CANOCO" package [Campus Software, Wageningen]. The soil chemical data were again used in a logarithmic form for the reason stated above. The species abundance data were used in the form of the arithmetic mean abundance of each species across the quadrats for each site [not transformed in any way]. As observed previously with reference to the calculation of weighted mean indicator values, this places emphasis on the indicative potential of the commoner species. A De-trended Canonical Correspondence Analysis [DCCA] was performed in the same way for completeness.

Cluster Analysis and De-trended Correspondence Analysis

As the additional time required to perform these analyses is modest, it was decided to pursue them for interest. A cluster analysis was performed on the same mean vegetation abundance data as had been prepared for [D]CCA. This was carried-out using the "TWINSPAN" routine within the "VESPAN" package [Unit of Vegetation Science, University of Lancaster]. The same data were also used to perform De-trended Correspondence Analysis [DCA] within the "CANOCO" package. The output ordination of DCA can be compared with an ordination based on the soil chemical data alone [i.e. that from PCA] or with that produced by [D]CCA. For an axis-by-axis comparison, this can be performed with a simple linear regression approach

7.3 <u>Results of application of multi-variate statistical techniques</u>

Principal Components Analysis

As an initial output, the routine produces a correlation matrix between all the pairs of soil chemical variables [see Figure 7.3.1]. The following points should be noted:-

- with the exception of the two ammonium-N measures and loss-on-ignition, all the soil chemical variables are positively inter-correlated.

- the alternative measures of pH [in water and in $CaCl_2$] are strongly positively correlated [for top layer **r = 0.89**, for middle layer **r = 0.91**, for bottom layer **r = 0.94]**

- the two measures of nitrate-N [available and mineralisable] are strongly positively correlated **[r = 0.83].**

Figure 7.3.1

Correlation matrix for soil chemical variables

	pH [H_2O] top	pH [H_2O] middle	pH [H2O] bottom	pH [CaCl2] top	pH [CaCl2] middle	pH [CaCl2] bottom	Exch. Calcium	Exch. Magnesium	Exch. Potassium	Tot. Phosphorus	Av. NO_3-Nitrogen	Min. NO_3-Nitrogen	Av. NH_4-Nitrogen	Min. NH_4-Nitrogen	Loss-on-ignition
pH [H_2O] top	1.00														
pH [H_2O] middle	0.87	1.00													
pH [H_2O] bottom	0.74	0.89	1.00												
pH [$CaCl_2$] top	0.89	0.82	0.73	1.00											
pH [$CaCl_2$] middle	0.81	0.91	0.81	0.90	1.00										
pH [$CaCl_2$] bottom	0.72	0.84	0.94	0.79	0.90	1.00									
Exch. Calcium	0.68	0.75	0.77	0.77	0.78	0.82	1.00								
Exch. Magnesium	0.69	0.61	0.52	0.61	0.50	*0.41*	*0.42*	1.00							
Exch. Potassium	*0.49*	0.50	*0.41*	*0.47*	*0.38*	*0.31*	*0.48*	0.71	1.00						
Tot. Phosphorus	*0.44*	0.55	0.52	0.53	0.57	0.52	*0.44*	*0.33*	*0.28*	1.00					
Av. NO_3-Nitrogen	0.55	0.66	0.64	0.65	0.60	0.58	0.53	0.53	0.64	0.60	1.00				
Min. NO_3-Nitrogen	0.60	0.62	0.63	0.71	0.61	0.58	*0.49*	0.50	*0.45*	0.60	0.83	1.00			
Av. NH_4-Nitrogen	*-0.26*	*-0.30*	*-0.32*	*-0.34*	*-0.39*	*-0.36*	*-0.22*	*-0.07*	*0.02*	*-0.19*	*-0.16*	*-0.26*	1.00		
Min. NH4-Nitrogen	*0.02*	*0.05*	*-0.02*	*-0.04*	*-0.06*	*-0.08*	*-0.06*	*0.23*	*0.27*	*-0.07*	*0.21*	*-0.11*	0.58	1.00	
Loss-on-ignition	*0.05*	*0.02*	*-0.04*	*-0.05*	*-0.08*	*-0.10*	*-0.03*	*0.15*	*0.25*	*0.08*	*0.13*	*0.00*	*0.08*	*0.40*	1.00

The loadings of the individual soil chemical variables on the first three principal components, for both runs, are displayed in Figures 7.3.2 and 7.3.3. The convention is adopted that the modulus of a loading must exceed 0.30 to be an important contribution to an axis. A total of 84% of the variation is explained by the first three principal components. No other component exceeds 5% explanatory power.

A number of major features emerge from these analyses [see Figures 7.3.2 to 7.3.4]:-

- The use of the different measures of pH has only a modest effect upon the outcome of the Principal Components Analysis.

- The first principal component explains **~65%** of inter-site variation and is apparently an axis of soil "base status" [pH and calcium supply], which rises with the "+ ve" direction. It should be observed that the inclusion in the analysis of several inter-correlated variables related to base status may act to emphasise the apparent strength of this component.

- The second principal component explains **~10%** of inter-site variation and is apparently an axis of soil nitrate-N supply, which rises with the "-ve" direction.

- The third principal component would appear to be primarily an axis of soil ammonium-N supply, with an influence from certain base cations [calcium/ magnesium] in the same sense.

- Total phosphorus, extractable potassium and loss-on-ignition appear less important than the other variables in explaining inter-site variation. They first occur with loading moduli > 0.3 as follows: phosphorus – on the 8th axis (which explains 1.1% of inter-site variation, potassium – on the 10th or 11th axis (no significant variation explained), loss-on-ignition – on the 9th or 12th axis (no significant variation explained). This does not remove the possibility

Figure 7.3.2

Principal Components Analysis [pH in H_2O] - Vector Loadings for Axes 1,2 & 3

PRINCIPAL COMPONENT	PC 1	PC 2	PC 3
VARIATION EXPLAINED	**0.65**	**0.10**	**0.09**
LOADINGS:			
pH [TOP LAYER]	**0.30**	*0.15*	*-0.03*
pH [MIDDLE LAYER]	**0.46**	*0.14*	*-0.08*
pH [BOTTOM LAYER]	**0.63**	*0.10*	*-0.07*
EXCH. CALCIUM	**0.41**	*0.15*	**0.34**
EXCH. MAGNESIUM	*0.20*	*0.11*	*0.24*
EXCH. POTASSIUM	*0.08*	*0.00*	*0.20*
TOTAL PHOSPHORUS	*0.09*	*-0.17*	*0.02*
AV. NITRATE-N	*0.15*	**-0.60**	*0.11*
MIN. NITRATE-N	*0.19*	**-0.72**	*0.05*
AV. AMMONIUM-N	*-0.14*	*0.02*	**0.74**
MIN. AMMONIUM-N	*-0.08*	*0.08*	**0.46**
LOSS-ON-IGNITION	*0.00*	*0.01*	*0.06*

Figure 7.3.3

Principal Components Analysis [pH in $CaCl_2$] - Vector Loadings for Axes 1,2 & 3

PRINCIPAL COMPONENT	PC 1	PC 2	PC 3
VARIATION EXPLAINED	**0.66**	**0.09**	**0.09**
LOADINGS:			
pH [TOP LAYER]	**0.38**	*-0.01*	*0.01*
pH [MIDDLE LAYER]	**0.50**	*0.17*	*-0.11*
pH [BOTTOM LAYER]	**0.59**	*0.22*	*-0.04*
EXCH. CALCIUM	**0.36**	*-0.07*	**0.55**
EXCH. MAGNESIUM	*0.17*	*-0.07*	**0.35**
EXCH. POTASSIUM	*0.07*	*-0.13*	*0.21*
TOTAL PHOSPHORUS	*0.09*	*-0.15*	*-0.07*
AV. NITRATE-N	*0.13*	**-0.59**	*-0.19*
MIN. NITRATE-N	*0.20*	**-0.64**	**-0.31**
AV. AMMONIUM-N	*-0.14*	*-0.30*	**0.51**
MIN. AMMONIUM-N	*-0.10*	*-0.15*	**0.35**
LOSS-ON-IGNITION	*-0.01*	*-0.03*	*0.05*

Figure 7.3.4a
Soil chemical variable loadings on PC1 and PC2 [H2O]

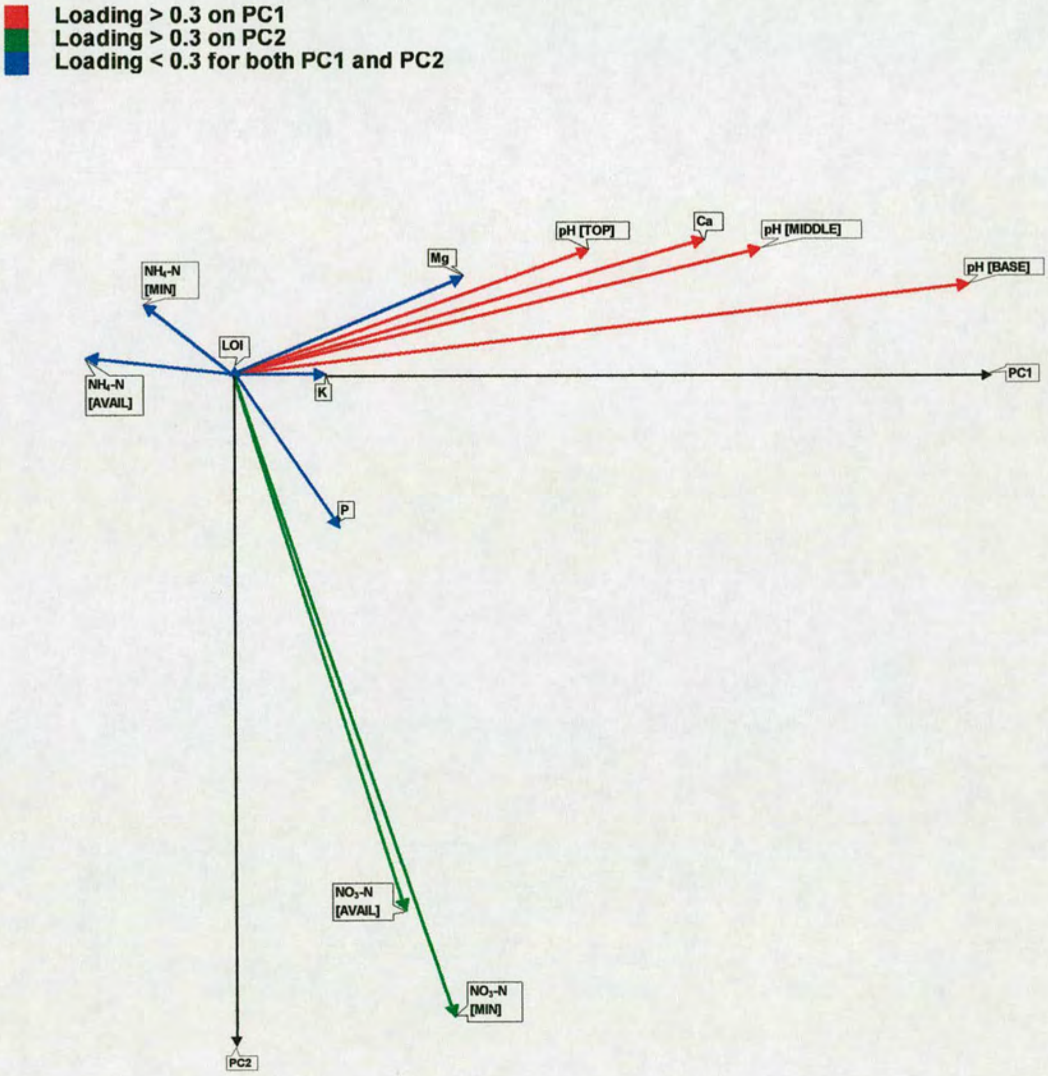
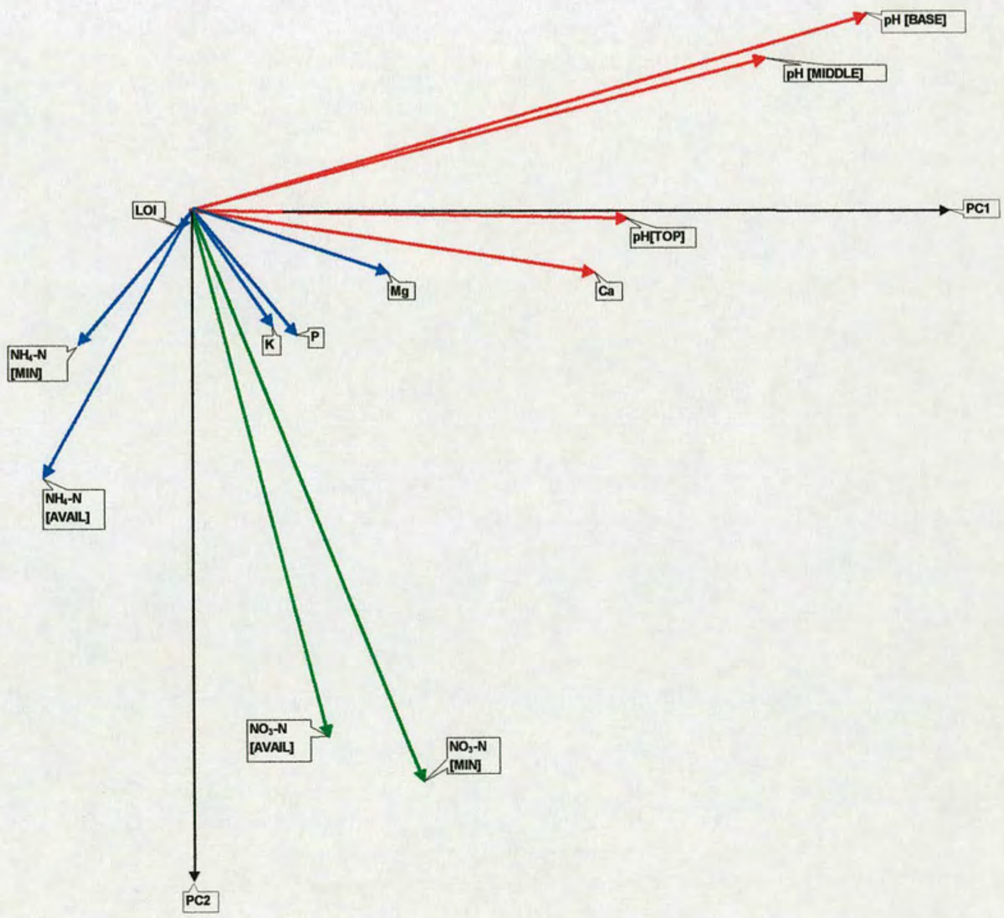


Figure 7.3.4b
Soil chemical variable loadings on PC1 and PC2 [CaCl2]

- Loading > 0.3 on PC1
- Loading > 0.3 on PC2
- Loading < 0.3 for both PC1 and PC2



that these variables may exert significant ecological influence on vegetation development and tree crop performance.

The first seven axes have been shown to be statistically discrete (non-degenerate) by the use of a "test of quality" routine within the GENSTAT 5 package.

These results of the PCA analysis are in agreement with those obtained by Hawkes, Pyatt & White (1997) in that pH / calcium and nitrate-N supply have again emerged as important descriptive variables. However, the fact that they appear separately on the first two, rather than together on the first principal component, implies that the production of a single scored ordination of "soil nutrient regime" is more problematic. It is considered desirable, for the practical operation of the forest site classification, to present an assessment of soil nutrient regime in this simplified form. However, it is clearly possible, for investigative purposes, to continue to examine the emergent axes of base status and nitrogen supply separately. Figures 7.3.5 and 7.3.6 illustrate the site scores on the first and second principal components individually [pH in water data run]. For convenience, the scores in each case are linearly re-scaled to match the observed range of Ellenberg mR values [1.04 to 7.18]. The correlation between the site mR value and site score on PC1 is **r = 0.71**. The correlation between the site mN value and site score on PC2 is **r = 0.33**. It should also be noted that the correlation between the site mN value and the site score on PC1 is **r = 0.63**. Hence both of the Ellenberg mean site indicator values are positively correlated with PC1. As PC1 explains the majority of inter-site variation [~65%], there is some evidence to suggest that it alone may represent the main trend of soil nutrient regime.

The following issues need to be considered in producing any composite ordination:-

- Such a single ordination would need to consider the position of each site on both of the first two axes. This could be accomplished by a linear combination of the normalised site scores produced by PCA on the first two axes. The issue to be decided is the relative weighting of the scores

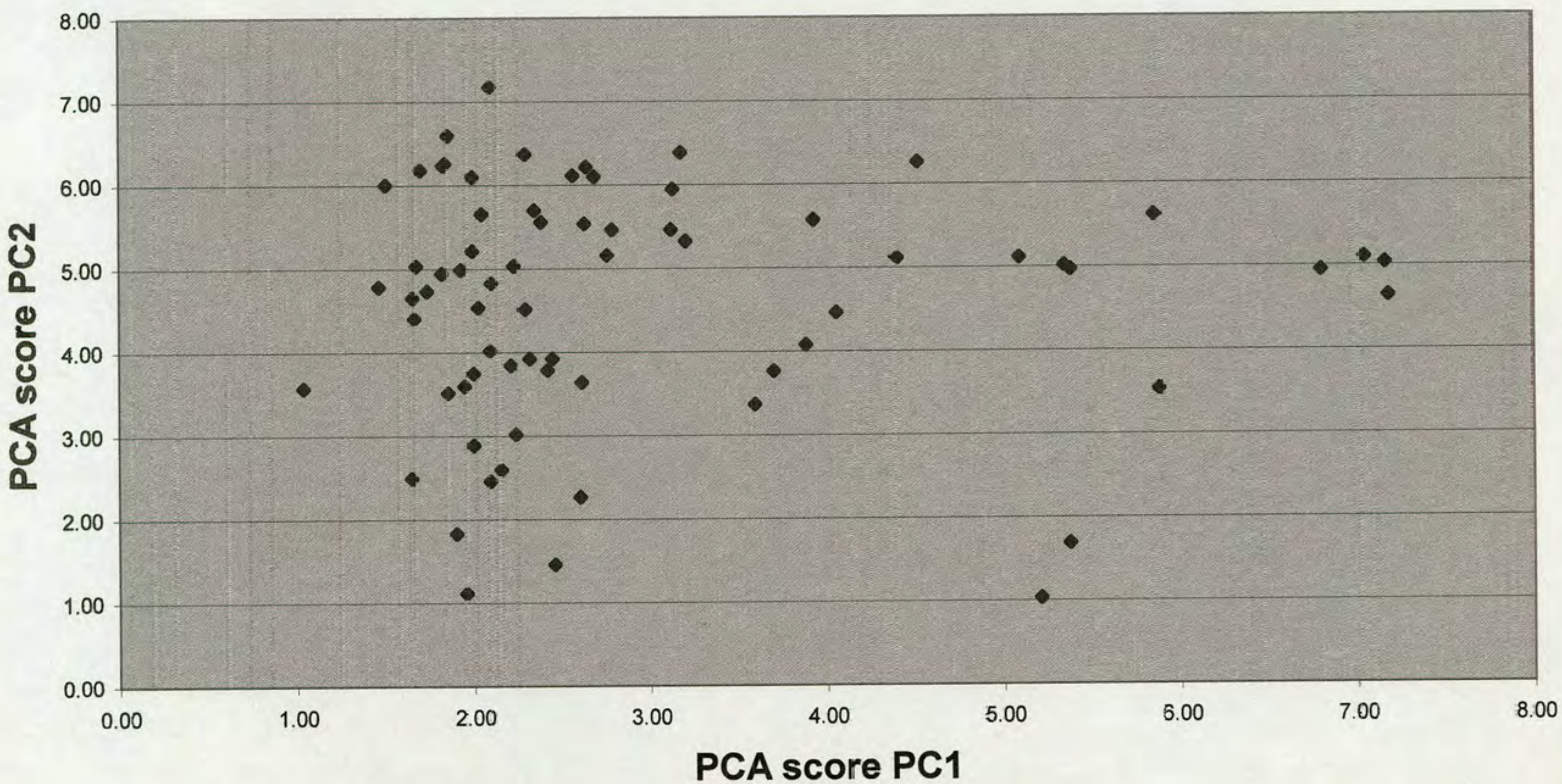
Figure 7.3.5
Site scores in PCA [H_2O] compared with Ellenberg mean site indicator values

Site code	PCA [H_2O] score PC1	PCA [H_2O] score PC2	Ellenberg score mR	Ellenberg score mN
ABF 1	5.37	1.84	3.02	6.60
ABF 2	2.24	3.47	2.00	3.00
AE 1	2.63	6.56	4.70	6.04
AE 2	3.70	4.39	3.97	5.93
AWE 1	2.76	6.09	3.40	5.40
BAL 1	2.61	4.23	1.88	2.33
BCH 1	3.13	7.06	3.93	5.76
BCH 2	1.70	7.34	2.80	4.39
CER 1	1.99	6.17	2.10	3.28
CHT 1	5.09	6.04	4.75	4.91
DEN 1	2.64	7.39	5.07	6.02
DEN 2	1.50	7.14	3.28	3.64
DEN 3	1.86	7.86	4.68	5.08
DEN 4	2.78	6.47	5.16	5.55
DEN 5	1.96	1.14	4.25	4.90
DEN 6	1.83	7.42	3.63	4.50
DEN 7	1.82	5.84	4.16	5.23
DOW 1	3.59	3.90	3.22	3.47
DOW 2	3.20	6.30	5.06	5.65
DOW 3	1.65	2.83	3.15	3.09
DOW 4	2.16	2.95	3.02	3.13
DOW 5	6.80	5.84	7.05	7.09
DOW 6	4.06	5.25	4.78	5.38
DST 1	4.52	7.44	6.92	6.15
GTN 1	2.21	4.49	3.36	3.45
INV 1	2.60	2.55	1.39	1.64
INV 2	2.09	2.78	3.95	5.02
KCD 1	1.66	5.48	2.01	3.02
KCD 2	1.47	5.64	2.33	3.41
KIN 1	2.00	4.36	1.70	2.28
KIN 2	2.09	4.69	3.46	5.47
LAK 1	2.29	7.58	2.94	4.50
LAK 2	2.09	8.57	4.67	5.09
LAK 3	2.38	6.58	3.89	5.75
LCH 1	2.29	5.31	2.82	4.08

Figure 7.3.5
Site scores in PCA [H_2O] compared with Ellenberg mean site indicator values

Site code	PCA [H_2O] score PC1	PCA [H_2O] score PC2	Ellenberg score mR	Ellenberg score mN
LND 1	5.21	1.04	4.94	6.11
LND 2	5.88	4.11	5.14	6.28
LOT 1	3.88	4.77	4.11	6.54
LOT 2	2.05	6.71	2.50	4.25
LWT 1	1.04	4.16	3.09	4.56
LWT 2	1.84	7.44	4.03	5.99
MCH 1	3.12	6.47	4.27	4.20
MCH 2	5.35	5.92	6.92	6.30
MID 1	2.23	5.95	2.90	3.29
MOR 1	2.03	5.33	2.19	1.79
MOR 2	2.45	4.58	1.04	1.04
MOR 3	1.86	4.08	1.05	1.06
NEW 1	2.46	1.56	3.03	2.98
NTH 1	3.93	6.61	5.35	5.21
NTH 2	7.16	5.95	6.78	7.23
NYM 1	5.38	5.86	4.91	6.46
SEA 1	2.00	3.31	1.28	1.22
SEW 1	1.67	5.17	2.06	3.11
SFD 1	2.68	7.25	4.63	5.85
SNT 1	2.42	4.41	2.00	2.06
SWD 1	7.18	5.45	6.73	6.10
SWD 2	1.74	5.58	3.79	5.14
SWD 3	1.68	5.95	4.03	4.92
SWP 1	3.17	7.60	4.80	6.10
SWP 2	2.32	4.58	2.92	3.39
SWP 3	2.35	6.75	3.42	4.35
TAY 1	2.57	7.27	2.44	3.45
TAY 2	5.85	6.66	7.18	8.57
THT 1	4.40	6.04	3.99	4.95
THT 2	1.95	4.18	2.26	3.29
THT 3	7.04	6.02	6.48	8.25
THT 4	2.10	5.69	4.59	5.86
THT 5	1.93	5.88	4.96	6.19
THT 6	1.99	7.25	3.14	3.52
WLD 1	1.90	2.01	3.01	2.91

Figure 7.3.6
PCA [H_2O] score PC1 v. PCA [H_2O] score PC2



from the two individual axes in producing the composite "score". Two possible options are (a) even weighting or (b) weighting by explanatory percentage.

- As the third ("ammonium-N") axis has an explanatory power comparable with that of the second ("nitrate-N") axis, one would need to consider whether the position of a site on the third axis should influence the overall scored ordination.

An example of a combined ordination is illustrated overleaf [see Figure 7.3.7] based on an evenly-weighted linear combination of the site scores on the first two principal components only [pH in water data run]. This is compared with a vegetative ordination based on the Ellenberg site mean indicator value mR. For convenience, both ordinations are scaled from 1.04 to 7.18 to match the range of mR-values recorded for the sites. These two ordinations have an inter-correlation coefficient of **r = 0.74** [see Figure 7.3.8]. This suggests that the mR value alone could be effective in predicting composite soil nutrient regime as defined in this particular way. The equivalent correlation for mR + mN is also **r = 0.74** and for mN alone **r = 0.69**.

There are a number of alternative ways in which a composite gradient of soil nutrient regime could be produced from the PCA results. These might lead to the conclusion that the use of the mR and mN values in linear combination remains the most effective approach, as was suggested by Hawkes, Pyatt & White (1997).

Figure 7.3.7
Comparative site ordination [ascending soil nutrient regime]

	Site code	PCA [H_2O] score PC1 + PC2	Site code	Ellenberg score mR
1	DEN 5	1.04	MOR 2	1.04
2	WLD 1	1.48	MOR 3	1.05
3	NEW 1	1.60	SEA 1	1.28
4	DOW 3	1.76	INV 1	1.39
5	INV 2	2.03	KIN 1	1.70
6	LWT 1	2.08	BAL 1	1.88
7	DOW 4	2.17	ABF 2	2.00
8	INV 1	2.25	SNT 1	2.00
9	SEA 1	2.26	KCD 1	2.01
10	ABF 2	2.51	SEW 1	2.06
11	MOR 3	2.58	CER 1	2.10
12	THT 2	2.70	MOR 1	2.19
13	KIN 1	2.84	THT 2	2.26
14	GTN 1	3.05	KCD 2	2.33
15	SEW 1	3.06	TAY 1	2.44
16	KIN 2	3.08	LOT 2	2.50
17	SNT 1	3.15	BCH 2	2.80
18	LND 1	3.17	LCH 1	2.82
19	BAL 1	3.18	MID 1	2.90
20	KCD 2	3.18	SWP 2	2.92
21	SWP 2	3.18	LAK 1	2.94
22	KCD 1	3.22	WLD 1	3.01
23	MOR 2	3.26	ABF 1	3.02
24	SWD 2	3.33	DOW 4	3.02
25	MOR 1	3.39	NEW 1	3.03
26	SWD 3	3.49	LWT 1	3.09
27	DEN 7	3.53	THT 6	3.14
28	LCH 1	3.55	DOW 3	3.15
29	THT 5	3.63	DOW 1	3.22
30	THT 4	3.63	DEN 2	3.28
31	DOW 1	3.65	GTN 1	3.36
32	ABF 1	3.72	AWE 1	3.40
33	CER 1	3.83	SWP 3	3.42
34	MID 1	3.86	KIN 2	3.46
35	AE 2	3.99	DEN 6	3.63

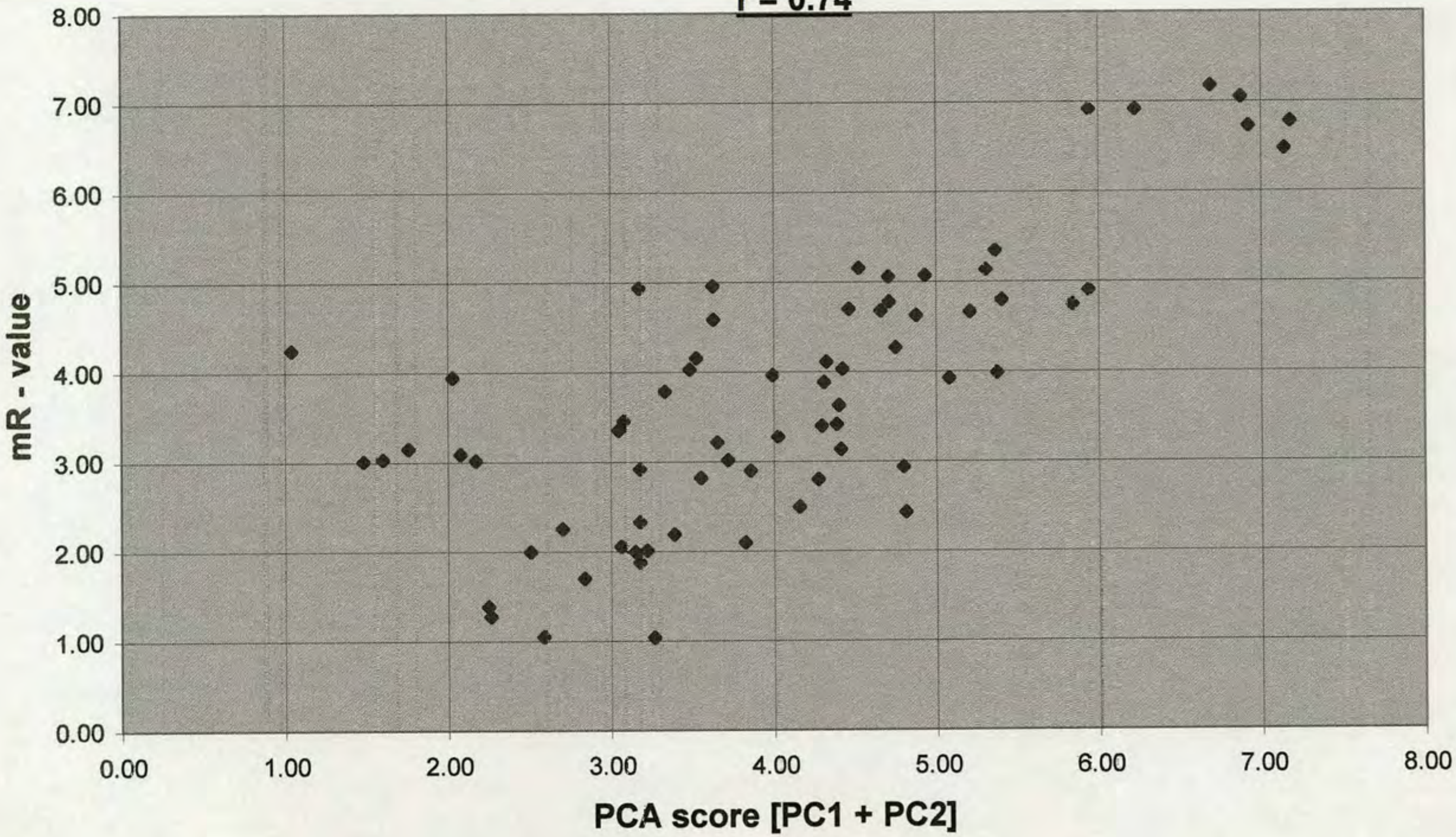
Figure 7.3.7
Comparative site ordination [ascending soil nutrient regime]

	Site code	PCA [H_2O] score PC1 + PC2	Site code	Ellenberg score mR
36	DEN 2	4.03	SWD 2	3.79
37	LOT 2	4.16	LAK 3	3.89
38	BCH 2	4.27	BCH 1	3.93
39	AWE 1	4.30	INV 2	3.95
40	LAK 3	4.31	AE 2	3.97
41	LOT 1	4.33	THT 1	3.99
42	SWP 3	4.39	LWT 2	4.03
43	DEN 6	4.40	SWD 3	4.03
44	THT 6	4.41	LOT 1	4.11
45	LWT 2	4.42	DEN 7	4.16
46	AE 1	4.46	DEN 5	4.25
47	DEN 4	4.53	MCH 1	4.27
48	DEN 3	4.66	THT 4	4.59
49	DOW 2	4.71	SFD 1	4.63
50	DOW 6	4.71	LAK 2	4.67
51	MCH 1	4.75	DEN 3	4.68
52	LAK 1	4.80	AE 1	4.70
53	TAY 1	4.81	CHT 1	4.75
54	SFD 1	4.88	DOW 6	4.78
55	DEN 1	4.93	SWP 1	4.80
56	BCH 1	5.08	NYM 1	4.91
57	LAK 2	5.21	LND 1	4.94
58	LND 2	5.31	THT 5	4.96
59	NTH 1	5.37	DOW 2	5.06
60	THT 1	5.38	DEN 1	5.07
61	SWP 1	5.41	LND 2	5.14
62	CHT 1	5.84	DEN 4	5.16
63	NYM 1	5.94	NTH 1	5.35
64	MCH 2	5.94	THT 3	6.48
65	DST 1	6.23	SWD 1	6.73
66	TAY 2	6.69	NTH 2	6.78
67	DOW 5	6.88	DST 1	6.92
68	SWD 1	6.92	MCH 2	6.92
69	THT 3	7.14	DOW 5	7.05
70	NTH 2	7.18	TAY 2	7.18

Figure 7.3.8

PCA [H_2O] score [PC1 + PC2] v. mR-value

r = 0.74



Canonical Correlation Analysis

The first output from this technique is also a correlation matrix between the soil chemical variables, which is, by definition, identical to that produced by PCA [see Figure 7.3.1]. However the Ellenberg site mean indicator values mR and mN calculated in Chapter 5 are now included [see Figure 7.3.9].

The following important points should be noted from these correlations:-

- The Ellenberg site mean indicator values mR and mN are strongly positively inter-correlated **[r = 0.88].** Hence across the 70 sites sampled they convey similar ecological information.

- Both the mR and mN values are positively correlated with all the soil chemical variables except the ammonium-N and loss-on-ignition measures. However the mR value appears to have the stronger correlations with soil chemical variables, including with both nitrate-N measures.

The Canonical Correlation Analysis was performed twice using the two sets of pH data, in the same way as for Principal Components Analysis.

Each "run" of the COR routine produces two orthogonal canonical axes. Each can be described as a linear combination of either the soil chemical variables or of the mR and mN values. For points lying exactly on the axes, these two functions are equal, but for all real site points they will differ. The correlation coefficients for individual chemical variables displayed [see Figures 7.3.10 and 7.3.11] use the linear combination of chemical variables to generate the axes.

All four canonical axes were formally shown to be significant at the $P>0.0001$ level.

Figure 7.3.9
Correlations between soil chemical variables and site Ellenberg mR and mN - values

	mR	mN
pH [H_2O] top	**0.56**	*0.43*
pH [H_2O] middle	**0.62**	**0.58**
pH [H_2O] bottom	**0.59**	**0.55**
pH [$CaCl_2$] top	**0.72**	**0.59**
pH [$CaCl_2$] middle	**0.61**	**0.59**
pH [$CaCl_2$] bottom	**0.56**	**0.53**
Exch. Calcium	**0.70**	**0.57**
Exch. Magnesium	**0.58**	*0.46*
Exch. Potassium	**0.55**	*0.32*
Tot. Phosphorus	**0.53**	**0.64**
Av. NO_3-Nitrogen	**0.60**	**0.52**
Min. NO_3-Nitrogen	**0.66**	**0.61**
Av. NH_4-Nitrogen	*-0.14*	*-0.16*
Min. NH4-Nitrogen	*-0.32*	*-0.37*
Loss-on-ignition	*-0.11*	*-0.19*

Figure 7.3.10
Correlations between soil chemical variables and COR [H_2O] axes 1 & 2

CANONICAL AXIS	**1**	**2**
VARIATION EXPLAINED	**0.72**	**0.28**
NUTRIENT CORRELATIONS:-		
pH [TOP LAYER]	$\boxed{\textbf{0.64}}$	*-0.19*
pH [MIDDLE LAYER]	$\boxed{\textbf{0.72}}$	*0.06*
pH [BOTTOM LAYER]	$\boxed{\textbf{0.69}}$	*0.06*
EXCH. CALCIUM	$\boxed{\textbf{0.81}}$	*-0.15*
EXCH. MAGNESIUM	$\boxed{\textbf{0.67}}$	*-0.17*
EXCH. POTASSIUM	$\boxed{\textbf{0.62}}$	$\boxed{\textbf{-0.51}}$
TOTAL PHOSPHORUS	$\boxed{\textbf{0.63}}$	*0.47*
AV. NITRATE-NITROGEN	$\boxed{\textbf{0.69}}$	*-0.04*
MIN. NITRATE-NITROGEN	$\boxed{\textbf{0.76}}$	*0.07*
AV. AMMONIUM-NITROGEN	*-0.17*	*-0.10*
MIN. AMMONIUM-NITROGEN	*-0.38*	*-0.25*
LOSS-ON-IGNITION	*-0.13*	*-0.27*
ELLENBERG CORRELATIONS		
mR	**0.86**	*-0.02*
mN	**0.77**	*0.33*
CANONICAL CORRELATIONS		
"0.9448mR + 0.0622mN"	**0.86**	
"-1.8817mR + 2.1047mN"		**0.73**

Figure 7.3.11
Correlations between soil chemical variables and COR [$CaCl_2$] axes 1 & 2

CANONICAL AXIS	**1.00**	**2.00**
VARIATION EXPLAINED	**0.78**	**0.22**
NUTRIENT CORRELATIONS:-		
pH [TOP LAYER]	**0.81**	*0.15*
pH [MIDDLE LAYER]	**0.61**	*0.41*
pH [BOTTOM LAYER]	**0.56**	*0.34*
EXCH. CALCIUM	**0.78**	*0.16*
EXCH. MAGNESIUM	**0.66**	*0.09*
EXCH. POTASSIUM	**0.70**	*-0.25*
TOTAL PHOSPHORUS	**0.45**	**0.68**
AV. NITRATE-NITROGEN	**0.64**	*0.22*
MIN. NITRATE-NITROGEN	**0.68**	*0.35*
AV. AMMONIUM-NITROGEN	*-0.13*	*-0.16*
MIN. AMMONIUM-NITROGEN	*-0.28*	*-0.38*
LOSS-ON-IGNITION	*-0.05*	*-0.30*
ELLENBERG CORRELATIONS		
mR	**0.86**	*0.21*
mN	**0.63**	**0.51**
CANONICAL CORRELATIONS		
"1.4936mR - .6095mN"	**0.89**	
"-1.4842mR + 2.0155mN"		**0.73**

The following major points should be drawn from these analyses:-

- The first [major] canonical axis explains **70-80%** of the vegetation - environment variation in the site data, and is strongly positively correlated with all the soil chemical variables excepting ammonium-N and loss-on-ignition.

- The Ellenberg site mean indicator value mR alone can be used to predict the site score on this first canonical axis with **r = 0.86**. The use of both mR and mN in an optimised linear combination only achieves a minor improvement on this **[r = 0.89]**, and then only in the case of the COR results using the pH in calcium chloride data. This is due to the strong inter-correlation between the mR and mN values highlighted above.

- The second [minor] canonical axis does not appear to be of immediate ecological interest. It seems to be an orthogonal residual to the main soil nutrient gradient.

- The effect of using one or other of the sets of pH data on the outcome of the analysis is modest. The first canonical axis is similar, bearing in mind the strong correlation of mR and mN.

In this case the production of a scored ordination of the sites is straightforward, as only the first axis needs to be used to capture the vast majority of the variation. An ordination of the sites based on the "chemically-calculated" scores from the analysis using the pH in water data is presented, alongside an ordination based on the Ellenberg site mean indicator value mR alone [see Figure 7.3.12]. For convenience, they are both scaled from 1.04 to 7.18 to match the range of mR recorded for the sites. The vegetative prediction has a correlation coefficient of **r = 0.86** [see Figure 7.3.13].

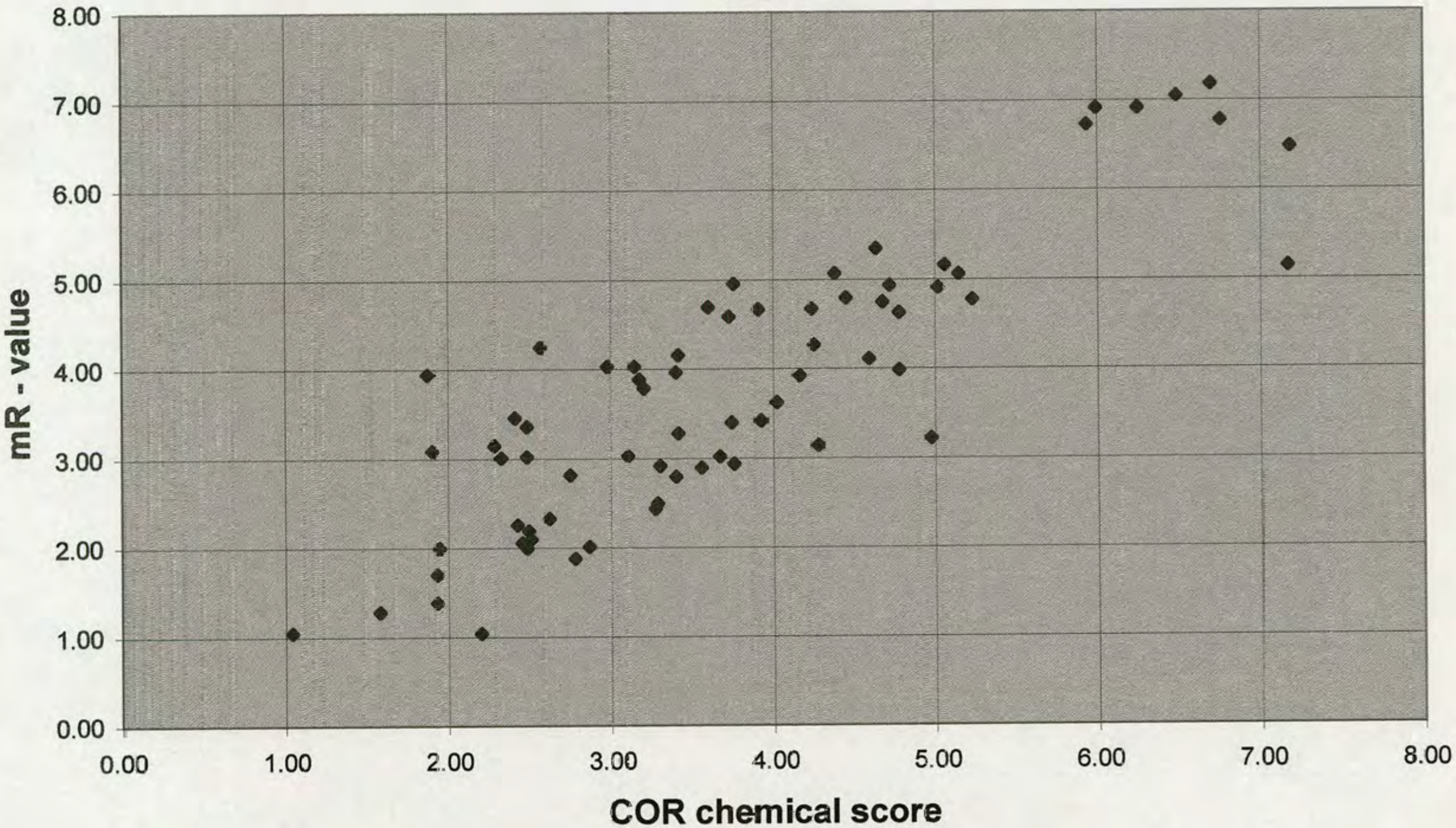
Figure 7.3.12
Comparative site ordination [ascending soil nutrient regime]

	Site code	COR [H2O] score [Axis 1 - chemical]	Site code	Ellenberg score mR
1	MOR 3	1.04	MOR 2	1.04
2	SEA 1	1.58	MOR 3	1.05
3	INV 2	1.87	SEA 1	1.28
4	LWT 1	1.90	INV 1	1.39
5	INV 1	1.93	KIN 1	1.70
6	KIN 1	1.93	BAL 1	1.88
7	ABF 2	1.95	ABF 2	2.00
8	MOR 2	2.20	SNT 1	2.00
9	DOW 3	2.28	KCD 1	2.01
10	WLD 1	2.33	SEW 1	2.06
11	KIN 2	2.41	CER 1	2.10
12	THT 2	2.43	MOR 1	2.19
13	SEW 1	2.45	THT 2	2.26
14	DOW 4	2.48	KCD 2	2.33
15	GTN 1	2.48	TAY 1	2.44
16	SNT 1	2.48	LOT 2	2.50
17	MOR 1	2.50	BCH 2	2.80
18	CER 1	2.51	LCH 1	2.82
19	DEN 5	2.57	MID 1	2.90
20	KCD 2	2.62	SWP 2	2.92
21	LCH 1	2.75	LAK 1	2.94
22	BAL 1	2.78	WLD 1	3.01
23	KCD 1	2.87	ABF 1	3.02
24	LWT 2	2.98	DOW 4	3.02
25	NEW 1	3.11	NEW 1	3.03
26	SWD 3	3.15	LWT 1	3.09
27	LAK 3	3.18	THT 6	3.14
28	SWD 2	3.20	DOW 3	3.15
29	TAY 1	3.28	DOW 1	3.22
30	LOT 2	3.29	DEN 2	3.28
31	SWP 2	3.30	GTN 1	3.36
32	AE 2	3.40	AWE 1	3.40
33	BCH 2	3.40	SWP 3	3.42
34	DEN 2	3.42	KIN 2	3.46
35	DEN 7	3.42	DEN 6	3.63

Figure 7.3.12
Comparative site ordination [ascending soil nutrient regime]

	Site code	COR [H2O] score [Axis 1 - chemical]	Site code	Ellenberg score mR
35	DEN 7	3.42	DEN 6	3.63
36	MID 1	3.56	SWD 2	3.79
37	AE 1	3.60	LAK 3	3.89
38	ABF 1	3.67	BCH 1	3.93
39	THT 4	3.73	INV 2	3.95
40	AWE 1	3.74	AE 2	3.97
41	LAK 1	3.76	THT 1	3.99
42	THT 5	3.76	LWT 2	4.03
43	LAK 2	3.91	SWD 3	4.03
44	SWP 3	3.93	LOT 1	4.11
45	DEN 6	4.03	DEN 7	4.16
46	BCH 1	4.17	DEN 5	4.25
47	DEN 3	4.24	MCH 1	4.27
48	MCH 1	4.25	THT 4	4.59
49	THT 6	4.28	SFD 1	4.63
50	DEN 1	4.38	LAK 2	4.67
51	SWP 1	4.45	DEN 3	4.68
52	LOT 1	4.59	AE 1	4.70
53	NTH 1	4.63	CHT 1	4.75
54	CHT 1	4.68	DOW 6	4.78
55	LND 1	4.72	SWP 1	4.80
56	SFD 1	4.77	NYM 1	4.91
57	THT 1	4.77	LND 1	4.94
58	DOW 1	4.97	THT 5	4.96
59	NYM 1	5.02	DOW 2	5.06
60	DEN 4	5.06	DEN 1	5.07
61	DOW 2	5.14	LND 2	5.14
62	DOW 6	5.23	DEN 4	5.16
63	SWD 1	5.94	NTH 1	5.35
64	DST 1	5.99	THT 3	6.48
65	MCH 2	6.25	SWD 1	6.73
66	DOW 5	6.49	NTH 2	6.78
67	TAY 2	6.70	DST 1	6.92
68	NTH 2	6.76	MCH 2	6.92
69	LND 2	7.17	DOW 5	7.05
70	THT 3	7.18	TAY 2	7.18

Figure 7.3.13
COR [H2O] chemical score v. mR-value
r = 0.86



[De-trended] Canonical Correspondence Analysis

The [D]CCA routine was performed once, using all the soil chemical variables [i.e. both sets of pH data simultaneously]. The de-trended [DCCA] version [by cubic polynomial method] has an identical first axis to that from CCA. However, the minor axes lose all their residual correlations with environmental variables having r >0.5.

The correlation matrix produced is identical to that for Principal Components Analysis [see Figure 7.3.1].

As with canonical correlation analysis [COR] above, the score calculated (a) by the use of the internally-generated species scores, and (b) by the use of the linear combination of soil chemical variables, will be equal only for points actually on the axes, and hence for all real site points they will differ. The correlation coefficients for individual chemical variables displayed [see Figure 7.3.14] use the linear combination of chemical variables to generate the axis.

The first [D]CCA axis was subjected to a formal Monte Carlo permutation test of significance, and proved significant at the P>0.01 level.

The following points are of note from the [D]CCA:-

- The first [D]CCA canonical axis is positively correlated with all the soil chemical variables excepting ammonium-N and loss-on-ignition. This axis is similar to the first canonical axis within the COR analysis above. The strength of the inter-correlation between these two ordinations is **r = 0.94.**

- The second and subsequent CCA canonical axes do not appear to be related to the soil chemical variables included in this study. When the analysis is de-trended, they have no remaining correlations with individual soil chemical variables. Here again, a scored ordination of the 70 sample

Figure 7.3.14
Correlations between soil chemical variables and [D]CCA Axis 1

FIRST CANONICAL AXIS	CORRELATION COEFFICIENT r	CANONICAL COEFFICIENT [applied to $\log_{10}$ values]
pH [H_2O][TOP LAYER]	0.59	-74
pH [H_2O][MIDDLE LAYER]	0.68	53
pH [H_2O][BOTTOM LAYER]	0.65	75
pH [$CaCl_2$][TOP LAYER]	0.72	93
pH [$CaCl_2$][MIDDLE LAYER]	0.64	-10
pH [$CaCl_2$][BOTTOM LAYER]	0.59	-84
EXCH. CALCIUM	0.73	-6
EXCH. MAGNESIUM	0.63	11
EXCH. POTASSIUM	0.62	12
TOTAL PHOSPHORUS	0.56	7
AV. NITRATE-NITROGEN	0.68	34
MIN. NITRATE-NITROGEN	0.66	-7
AV. AMMONIUM-NITROGEN	*-0.09*	43
MIN. AMMONIUM-NITROGEN	*-0.16*	-39
LOSS-ON-IGNITION	*0.01*	-9

ELLENBERG CORRELATION

mR	0.89	
CANONICAL CORRELATION	0.94	

sites can be based on the first canonical axis only [see Figure 7.3.15]. The scores in Figure 7.3.15. have been re-scaled over the same range as the site mR values, for the sake of consistency. The site and species scores for axes 1 to 4 in [D]CCA are presented in Appendix 5 [with original scaling].

- The explanatory power of the first [D]CCA canonical axis [21 %] may appear at first sight to be less than that of the first canonical axis produced by COR [72%]. This however is to be expected:- sites with identical soil nutrient regime can have different vegetation species composition, as there are many species that are suited to any particular regime. Whereas the use of the Ellenberg site mean indicator values in the COR analysis treats such sites as ecologically identical, they appear completely different in the raw vegetation data used by the [D]CCA analysis. A large amount of species-environment variation which is not explicable by soil nutrient regime remains active in the [D]CCA analysis, whereas it is implicitly suppressed in the COR analysis. Hence the [D]CCA axis may well explain the same or a greater proportion of the species: soil nutrient regime variation.

The correlation coefficient of the internally generated vegetation species composition "score" with the "chemical score" on the first [D]CCA canonical axis is **r = 0.94** [see Figure 7.3.17]. This compares with **r = 0.86** for the site mean Ellenberg indicator value mR with the first COR canonical axis [see Figure 7.3.13]. It should be noted that mR is correlated with the first [D]CCA axis with **r = 0.89** [see Figure 7.3.16]. This suggests that the use of internally generated species indicator values as opposed to Ellenberg indicator values might have the potential to enhance the accuracy of soil nutrient regime prediction.

Figure 7.3.15
Comparative site ordination [ascending soil nutrient regime]

	Site code	[D]CCA score [Axis 1 - chemical]	Site code	[D]CCA score [Axis 1 - vegetative]	Site code	Ellenberg score mR
1	SEA 1	1.04	SEA 1	1.04	MOR 2	1.04
2	INV 2	1.65	MOR 3	1.27	MOR 3	1.05
3	MOR 3	1.87	MOR 2	1.29	SEA 1	1.28
4	MOR 2	2.08	INV 1	1.70	INV 1	1.39
5	INV 1	2.66	KIN 1	1.88	KIN 1	1.70
6	SNT 1	2.84	BAL 1	2.02	BAL 1	1.88
7	MOR 1	2.91	MOR 1	2.35	ABF 2	2.00
8	BAL 1	2.94	SNT 1	2.52	SNT 1	2.00
9	LWT 1	2.95	ABF 2	2.58	KCD 1	2.01
10	CER 1	2.97	KCD 1	2.65	SEW 1	2.06
11	ABF 2	3.04	THT 2	2.73	CER 1	2.10
12	KIN 1	3.04	SEW 1	2.74	MOR 1	2.19
13	LCH 1	3.04	CER 1	2.75	THT 2	2.26
14	SEW 1	3.07	KCD 2	2.81	KCD 2	2.33
15	KCD 2	3.08	INV 2	3.07	TAY 1	2.44
16	KIN 2	3.14	LCH 1	3.23	LOT 2	2.50
17	LAK 3	3.15	KIN 2	3.41	BCH 2	2.80
18	GTN 1	3.26	WLD 1	3.45	LCH 1	2.82
19	BCH 2	3.31	DOW 3	3.49	MID 1	2.90
20	WLD 1	3.31	LWT 1	3.49	SWP 2	2.92
21	KCD 1	3.36	AWE 1	3.50	LAK 1	2.94
22	THT 2	3.43	GTN 1	3.53	WLD 1	3.01
23	DEN 2	3.49	MID 1	3.57	ABF 1	3.02
24	SWD 2	3.52	BCH 2	3.58	DOW 4	3.02
25	SWD 3	3.59	LOT 2	3.59	NEW 1	3.03
26	DOW 3	3.65	SWP 2	3.59	LWT 1	3.09
27	NEW 1	3.69	NEW 1	3.61	THT 6	3.14
28	SWP 2	3.83	DOW 4	3.62	DOW 3	3.15
29	LOT 2	3.91	THT 6	3.73	DOW 1	3.22
30	LWT 2	3.95	AE 2	3.76	DEN 2	3.28
31	MID 1	3.97	SWP 3	3.76	GTN 1	3.36
32	ABF 1	3.99	LWT 2	3.80	AWE 1	3.40
33	DOW 4	4.01	LAK 3	3.81	SWP 3	3.42
34	TAY 1	4.08	BCH 1	3.86	KIN 2	3.46
35	AWE 1	4.15	DEN 2	3.88	DEN 6	3.63

Figure 7.3.15
Comparative site ordination [ascending soil nutrient regime]

	Site code	CCA score [Axis 1 - chemical]	Site code	CCA score [Axis 1 - vegetative]	Site code	Ellenberg score mR
36	DEN 7	4.15	DOW 1	3.89	SWD 2	3.79
37	AE 2	4.20	ABF 1	3.97	LAK 3	3.89
38	THT 1	4.20	TAY 1	3.97	BCH 1	3.93
39	DEN 5	4.37	SWD 2	3.98	INV 2	3.95
40	LAK 1	4.39	SWD 3	4.05	AE 2	3.97
41	LAK 2	4.43	THT 1	4.05	THT 1	3.99
42	AE 1	4.46	LOT 1	4.06	LWT 2	4.03
43	BCH 1	4.54	DEN 7	4.09	SWD 3	4.03
44	DOW 1	4.54	AE 1	4.13	LOT 1	4.11
45	SWP 3	4.54	LAK 1	4.18	DEN 7	4.16
46	THT 5	4.62	THT 4	4.22	DEN 5	4.25
47	THT 4	4.72	DEN 6	4.28	MCH 1	4.27
48	LOT 1	4.78	LAK 2	4.40	THT 4	4.59
49	DEN 6	4.82	SWP 1	4.52	SFD 1	4.63
50	DEN 1	4.85	LND 1	4.53	LAK 2	4.67
51	THT 6	4.91	THT 5	4.53	DEN 3	4.68
52	CHT 1	4.95	SFD 1	4.65	AE 1	4.70
53	DOW 2	4.98	DEN 3	4.67	CHT 1	4.75
54	NTH 1	5.05	MCH 1	4.67	DOW 6	4.78
55	LND 1	5.08	CHT 1	4.71	SWP 1	4.80
56	SFD 1	5.12	LND 2	4.71	NYM 1	4.91
57	SWP 1	5.17	DEN 1	4.72	LND 1	4.94
58	DEN 3	5.20	NTH 1	4.88	THT 5	4.96
59	NYM 1	5.28	NYM 1	4.88	DOW 2	5.06
60	MCH 1	5.33	DEN 5	4.89	DEN 1	5.07
61	DOW 6	5.34	DOW 2	4.89	LND 2	5.14
62	DEN 4	5.63	DEN 4	4.91	DEN 4	5.16
63	LND 2	5.96	DOW 6	5.05	NTH 1	5.35
64	DST 1	6.27	DST 1	5.52	THT 3	6.48
65	TAY 2	6.54	SWD 1	6.36	SWD 1	6.73
66	SWD 1	6.82	DOW 5	6.83	NTH 2	6.78
67	THT 3	6.83	NTH 2	6.86	DST 1	6.92
68	DOW 5	6.95	THT 3	6.98	MCH 2	6.92
69	MCH 2	7.15	MCH 2	6.99	DOW 5	7.05
70	NTH 2	7.18	TAY 2	7.18	TAY 2	7.18

Figure 7.3.16
[D]CCA chemical score v. mR-value
r = 0.89

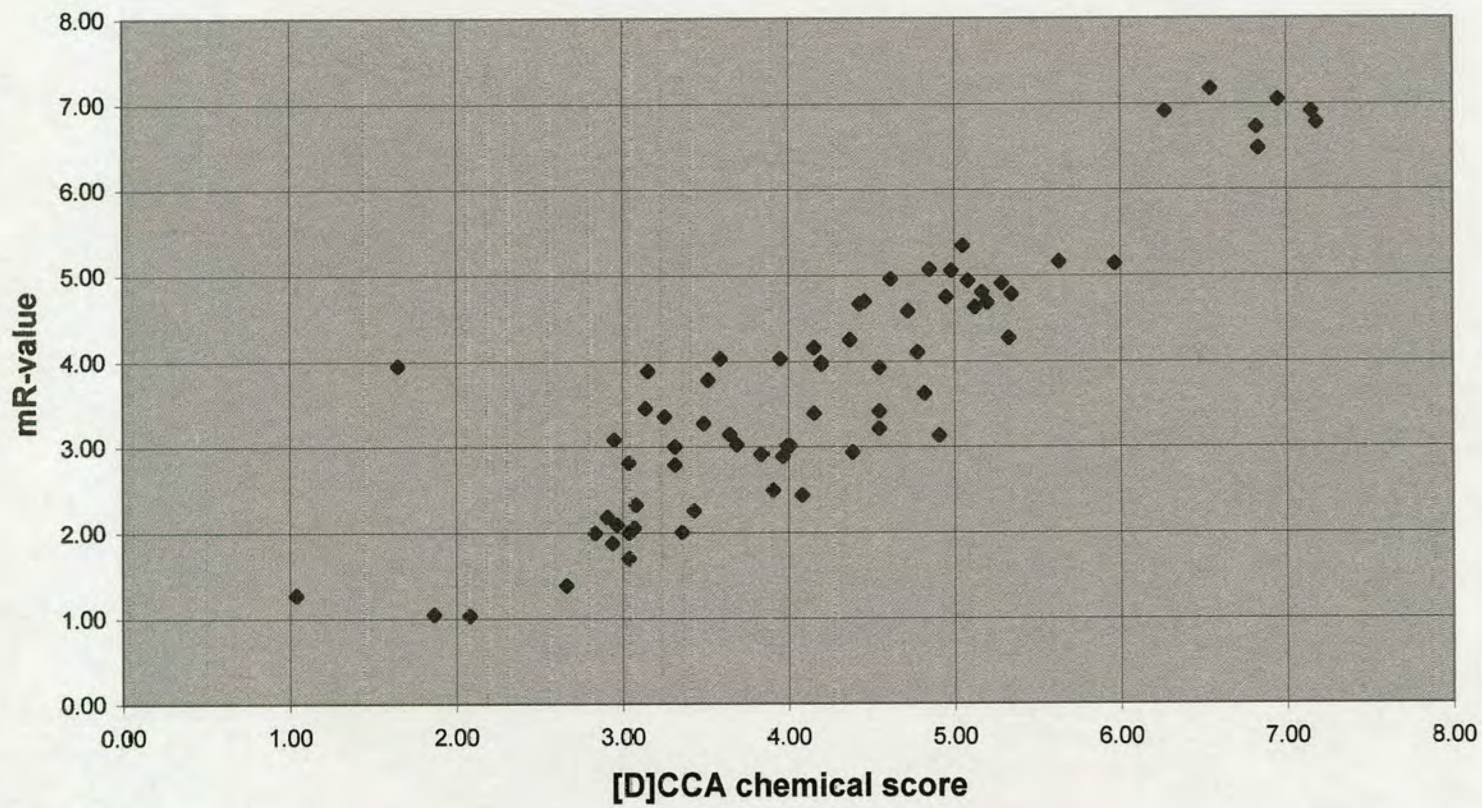
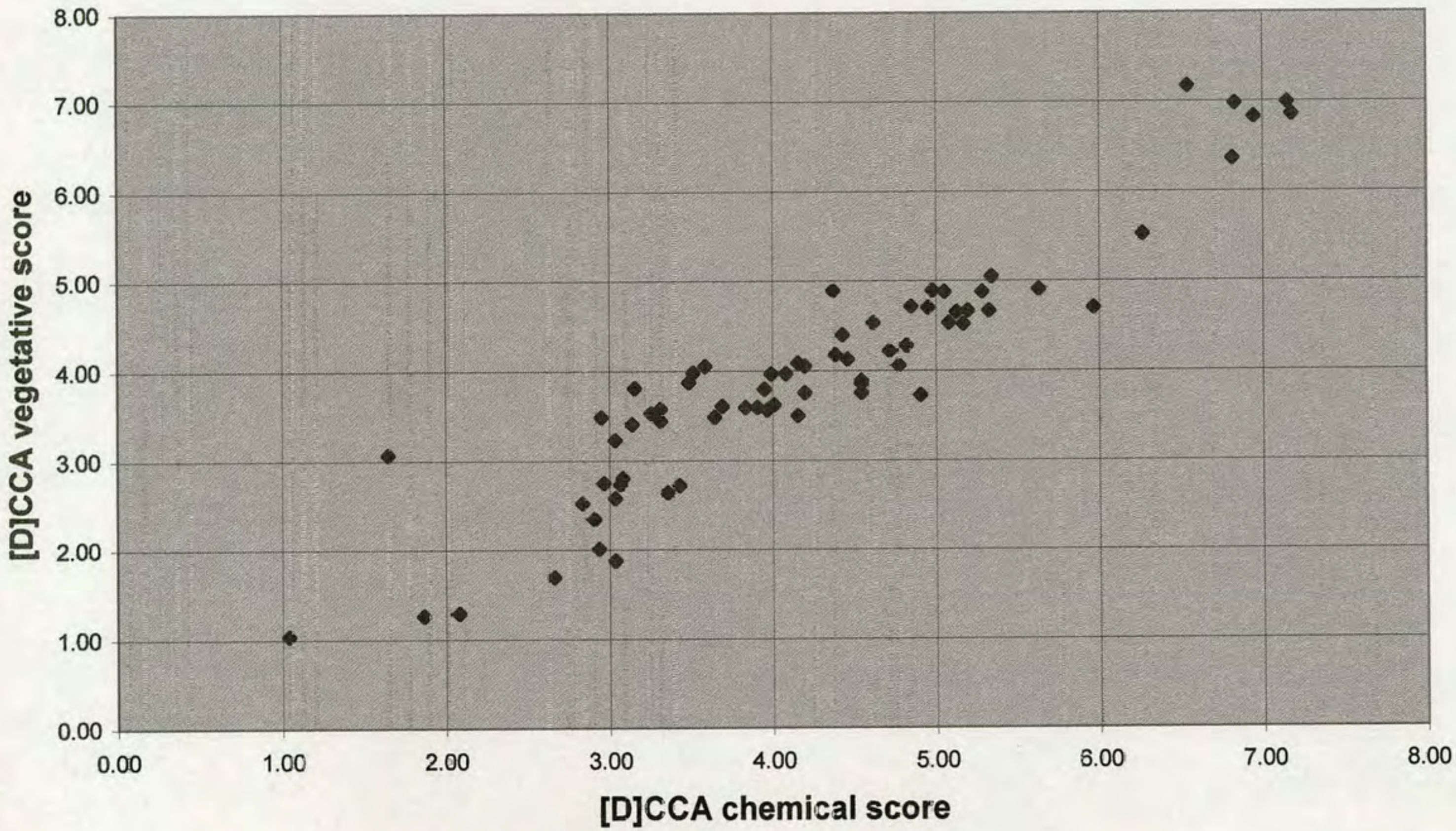


Figure 7.3.17
[D]CCA chemical score v. vegetative score
r = 0.94



Cluster Analysis and De-trended Correspondence Analysis

These analyses were undertaken as a subsidiary exercise, largely for completeness.

The Cluster Analysis was performed using the TWINSPAN routine. Some of the groupings of species produced were recognisable as corresponding to the "visually-dominant vegetation types" described in Chapter 5 [especially those at the extremes of the implied range of soil nutrient regime]. Many, though, were not field-identifiable groupings. The analysis produced a number of groupings with either too few or too many species for practical use. Overall the TWINSPAN analysis did not produce species groupings as immediately recognisable as the ones set out in Chapter 5 [N.V.C sub-communities and "visually- dominant vegetation types"]

The De-trended Correspondence Analysis [DCA] used the mean species abundance data prepared for use in [D]CCA, and was also run within the CANOCO routine-set [polynomial de-trending was employed]. The site scores on the first axis produced indicated that it was markedly similar to the first axis produced from [D]CCA. These two axes are indeed correlated with **r = 0.83** [using the species scores to generate the [D]CCA axis]. This helps to confirm that the major axis of variation in ground vegetation species composition does indeed reflect soil nutrient conditions. The site and species scores for axes 1 to 4 in DCA are presented in Appendix 5 [with original scaling].

7.4 Summary of results of statistical analysis

The following major points are presented in summary of the outcome of the multi-variate statistical analyses described:-

- Principal Components Analysis [PCA], Canonical Correlations Analysis [COR] and [De-trended] Canonical Correspondence Analysis [[D]CCA] are in agreement in revealing a major gradient of soil nutrient regime throughout the 70 sites studied. This gradient is mainly described by inter-correlated measures of soil pH, extractable calcium and available and mineralisable nitrate-N. Total phosphorus, extractable magnesium and extractable potassium appear less important within PCA, but rise together with the main gradient of soil nutrient regime in the canonical ordinations COR and [D]CCA - hence they may well influence vegetation species composition. Measures of ammonium-N and of loss-on-ignition are weakly counter-valent to this main gradient, for the sites sampled in this study.

- The analyses presented suggest that vegetation species composition can be used to predict the score for a site on this main gradient of soil nutrient regime. The site mean Ellenberg indicator value mR is strongly correlated with the gradient in each case. The use of the scores for the species produced internally by the [D]CCA analysis has the potential to enhance the quality of the assessment produced.

The inter-correlations of the main ordinations described are reviewed in Figure 7.4.1.

Figure 7.4.1
Summary of correlations between site score ordinations

	Ellenberg mR-value	PCA - PC1 + PC2 [H_2O] score	COR chemical score	[D]CCA vegetative score	[D]CCA chemical score
Ellenberg mR-value	1.00				
PCA - PC1 + PC2 [H_2O] score	0.74	1.00			
COR chemical score	0.86	0.86	1.00		
[D]CCA vegetative score	0.95	0.75	0.88	1.00	
[D]CCA chemical score	0.89	0.80	0.94	0.94	1.00

8. DISCUSSION OF RESULTS

8.1 Selecting the most suitable defining gradient of soil nutrient regime

To recall the central hypotheses as expressed in chapter 2:-

- That a set of quantified soil chemical variables can be defined which will explain the majority of the internal variation between the sites in terms of soil nutrient regime

- That a set of quantified soil chemical variables can be defined which will explain the majority of the nutrient-related variation in the species composition of the ground vegetation between the sites

- That the species composition of the ground vegetation can be used reliably to predict the status of either of these sets of soil chemical variables.

The first hypothesis is supported by the results of the Principal Components Analysis, where ~75% of the internal variation was explained by the first two axes:- [dominated by soil pH and calcium supply and by soil nitrate-N supply respectively].

The second hypothesis is supported by the results of Canonical Correlation Analysis where 72% of the variation was explained by the first axis. This was a composite gradient of soil base status and soil nitrate-N supply. The confirmation is strengthened by the results of [De-trended] Canonical Correspondence Analysis, where a similar first axis was produced.

The third hypothesis is supported by the strong correlations between the abundance-weighted Ellenberg site mean indicator value mR and the site score on each of the three ordinations. The use of the internally-generated species indicator values produced by the [De-trended] Canonical Correspondence Analysis appears to improve the predictive potential of the vegetation against all three ordinations, as might be expected.

In addition, evidence has been gained that those soil chemical measures which explain the greatest internal variation between the sites are also those which explain the greatest variation in the species composition of the ground vegetation. These are soil pH, soil calcium supply and soil nitrate-N supply. Other chemical variables also appear to have more minor influences on the vegetation species composition. The fact that unconstrained de-trended correspondence analysis [DCA] also highlights this gradient emphasises its significance in determining species composition, independently of the choice of chemical variables selected for measurement in this study.

The strong inter-relationships highlighted between the gradients of soil nutrient regime produced imply that it would be possible to use any of these as the basis for a valid quantitative definition. However it is proposed, for operational purposes, to use the gradient produced by [De-trended] Canonical Correspondence Analysis, for the following reasons:-

- It is more straightforward to produce an ordination of the sites from a single gradient, rather than from the two or three axes that may need to be considered within PCA. This would suggest using either the single COR or [D]CCA gradients.

- The vegetative prediction of the site score on the [D]CCA ordination is the most reliable, whether Ellenberg or internally derived species indicator values were to be used.

- The [D]CCA technique allows for the objective assignment of revised indicator values to species, both from this work and following future sampling including additional species.

The classified ordination of sites would thus be based on the first axis gradient within [De-trended] Canonical Correspondence Analysis, as defined by the corresponding linear combination of chemical variables.

8.2 Identifying the basis for the delineation of the soil nutrient classes

As explained in Chapter 2, it is proposed, for practical application, to divide the range of soil nutrient regime measured within this study into five classes to be called "very poor", "poor", "medium", "rich" and "very rich". It is possible that carbonate soils would have extended this range had they been able to be sampled sufficiently. It is to be noted that calcareous soils already dominate the upper sector of the present range of measured soil nutrient regime. The appropriateness of defining a separate "carbonate" soil nutrient class will be considered in the light of future sampling work. It is felt that the "very poor" class defined in this study will encompass the least fertile sites of practical significance for forestry purposes, although further sampling in this part of the range is a priority for the future.

The basis of division of the range into five classes is a matter of some importance. It is not *a priori* the case that they should each occupy the same range of nutrient score. Two possible rationales for the range division are suggested below:-

An equal division of the score range. This leads to the following classification [the linear re-scaling from 1.04 to 7.18, to match the range of observed mR values, is retained from Chapter 7]:-

Very poor:	[1.04 to 2.27]	occupied by 4 sites
Poor:	[2.27 to 3.50]	occupied by 19 sites
Medium:	[3.50 to 4.73]	occupied by 24 sites
Rich:	[4.73 to 5.96]	occupied by 15 sites
Very rich:	[5.96 to 7.18]	occupied by 8 sites

An alternative is a division of the score range which reflects the occurrence of the "visually-dominant vegetation types" of Chapter 5, proposed as follows:-

Very poor:	[1.04 to 2.95]	occupied by 8 sites
Poor:	[2.95 to 4.15]	occupied by 28 sites
Medium:	[4.15 to 4.92]	occupied by 15 sites
Rich:	[4.92 to 6.50]	occupied by 13 sites
Very rich:	[6.50 to 7.18]	occupied by 6 sites

The following broad correspondences are intended:-

Very poor: <u>Type A and B vegetation</u>

A: *Calluna vulgaris or Erica* spp. dominated

B: *Molinia caerulea* dominated

Poor: <u>Type C and D vegetation</u>

C: *Deschampsia flexuosa* dominated

D: *Pteridium aquilinum* dominated

Medium: <u>Type E, F and G vegetation</u>

E: *Rubus fruticosus* (+ *Pteridium aquilinum*) dominated

F: *Dryopteris spp./ Oxalis acetosella/ Rubus spp.* dominated

G: *Holcus* spp. and/ or *Agrostis* spp. dominated

Rich: <u>Type H vegetation</u>

H: Species rich vegetation

Very rich: <u>Type I and J vegetation</u>

I: *Mercurialis perennis* dominated

J: *Urtica dioica* dominated

Figure 8.2.1
Ordination of sites with SNR classes

	Site code	[D]CCA score [Axis 1 - chemical]	Soil nutrient class
1	SEA 1	1.04	Very poor
2	INV 2	1.65	Very poor
3	MOR 3	1.87	Very poor
4	MOR 2	2.08	Very poor
5	INV 1	2.66	Very poor
6	SNT 1	2.84	Very poor
7	MOR 1	2.91	Very poor
8	BAL 1	2.94	Very poor
9	LWT 1	2.95	Poor
10	CER 1	2.97	Poor
11	ABF 2	3.04	Poor
12	KIN 1	3.04	Poor
13	LCH 1	3.04	Poor
14	SEW 1	3.07	Poor
15	KCD 2	3.08	Poor
16	KIN 2	3.14	Poor
17	LAK 3	3.15	Poor
18	GTN 1	3.26	Poor
19	BCH 2	3.31	Poor
20	WLD 1	3.31	Poor
21	KCD 1	3.36	Poor
22	THT 2	3.43	Poor
23	DEN 2	3.49	Poor
24	SWD 2	3.52	Poor
25	SWD 3	3.59	Poor
26	DOW 3	3.65	Poor
27	NEW 1	3.69	Poor
28	SWP 2	3.83	Poor
29	LOT 2	3.91	Poor
30	LWT 2	3.95	Poor
31	MID 1	3.97	Poor
32	ABF 1	3.99	Poor
33	DOW 4	4.01	Poor
34	TAY 1	4.08	Poor
35	AWE 1	4.15	Poor
36	DEN 7	4.15	Poor

Figure 8.2.1
Ordination of sites with SNR classes

	Site code	[D]CCA score [Axis 1 - chemical]	Soil nutrient class
37	AE 2	4.20	Medium
38	THT 1	4.20	Medium
39	DEN 5	4.37	Medium
40	LAK 1	4.39	Medium
41	LAK 2	4.43	Medium
42	AE 1	4.46	Medium
43	BCH 1	4.54	Medium
44	DOW 1	4.54	Medium
45	SWP 3	4.54	Medium
46	THT 5	4.62	Medium
47	THT 4	4.72	Medium
48	LOT 1	4.78	Medium
49	DEN 6	4.82	Medium
50	DEN 1	4.85	Medium
51	THT 6	4.91	Medium
52	CHT 1	4.95	Rich
53	DOW 2	4.98	Rich
54	NTH 1	5.05	Rich
55	LND 1	5.08	Rich
56	SFD 1	5.12	Rich
57	SWP 1	5.17	Rich
58	DEN 3	5.20	Rich
59	NYM 1	5.28	Rich
60	MCH 1	5.33	Rich
61	DOW 6	5.34	Rich
62	DEN 4	5.63	Rich
63	LND 2	5.96	Rich
64	DST 1	6.27	Rich
65	TAY 2	6.54	Very rich
66	SWD 1	6.82	Very rich
67	THT 3	6.83	Very rich
68	DOW 5	6.95	Very rich
69	MCH 2	7.15	Very rich
70	NTH 2	7.18	Very rich

The advantage of an equal score range division is that it is entirely objective - there is no doubt about where to position the fixed boundaries between the soil nutrient classes. The disadvantage is that these boundaries separate sites that have similar ground vegetation assemblages, which may reduce the "intuitive" correspondence of the classes with field observations. The major advantage of a division based on vegetation assemblages is that it is more readily applied in the field, and can continue to be refined as further sampling is completed.

On balance a division of the score range reflecting the major "visually dominant vegetation types" is to be preferred. An ordinated classification on this basis of the 70 sites from the present study is displayed in Figure 8.2.1.

Ground vegetation species composition can now be used in two ways to recognise soil nutrient regime classes in the field:- (a) the use of the vegetatively-predicted site score [either the Ellenberg mR value or an equivalent produced using internally-generated species indicator values] (a **quantitative** means) and (b) the matching of the "visually-dominant vegetation type" (a **qualitative** means).

8.3 Assessing the reliability of soil nutrient regime assessment by vegetation

Assessing the reliability of these two diagnostic methods must be tackled in different ways.

The reliability of the quantitative method should be assessed using statistics which do not depend on the position of a site on the score range [i.e. they should operate "before" the imposition of class boundaries]. Once class boundaries are imposed sites close to them become prone to misclassification, although their soil nutrient score has been accurately predicted by the vegetation. Hence the temptation to examine "how many of the 70 sites are correctly classified" should be resisted, as it will not yield a meaningful statistic. Three statistics which are of use are:- (a) the strength of the linear correlation of predicted and measured soil nutrient scores (the "r-value"), (b) the mean score separation between predicted and measured soil nutrient scores across the 70 sites and (c) the proportion of sites for which this score separation is greater than the intended class range [i.e. where it would be impossible for the site to be correctly classified, wherever the boundaries fell]. Where, as is now proposed, the class ranges are not equal, the latter comparison must be made with the mean class width [in this case 1.228]. It should be noted, in the case of comparisons (b) and (c), that possible non-linearity ("skew") in the relationship between the Ellenberg mR values and the [D]CCA chemical scores may account for a proportion of the perceived improvement.

The use of the abundance-weighted Ellenberg site mean indicator value mR and the internally-generated [D]CCA vegetative site score are compared in these respects as predictors of the [D]CCA measured soil nutrient score, which is the gradient under classification.

	mR	**Internal score**
Linear Correlation [r-value]	0.89	0.94
Mean score separation [s]	0.45	0.27
Proportion of plots where s< 1.228	0.87	0.97

Although the performance of both predictive indices is quite satisfactory, the use of internally generated species scores offers the prospect of improving the reliability of soil nutrient regime assessments. The results of future sampling work will allow continued refinement of the internal species scores produced by the [D]CCA model. Figure 8.3.1a presents a comparison of Ellenberg R values [where available] and internal [D]CCA species scores for the most frequently encountered species [that is those present at 7 or more of the 70 sites]. These species usually set the range of the abundance-weighted site mean indicator value. The internal species scores are also shown linearly re-scaled for ease of comparison with the site scores of Figure 8.2.1. [see Figures 8.3.1a&b]. Abundance-weighted means of these “domestic” or “revised” species indicator values could potentially be used to produce a provisional site soil nutrient assessment based on these commoner species, which could be compared with the site Ellenberg mR value. Eventually it might be possible to combine the two sets of species indicator values to produce a joint assessment. However, care would need to be taken to achieve a compatible scaling, removing the possible influence of non-linearity (“skewing”). As more species are included in future sampling, this may become a valuable avenue to pursue.

The reliability of the qualitative method must be assessed in the light of the class boundaries selected, based on the 70 sites sampled. The statistic to be applied is a “reliability of matching” value. Hence if a site is decided to have a particular “visually-dominant vegetation type”, what is the probability that it falls into the corresponding class of soil nutrient regime? This is assessed from the sample population by the proportion of sites with that vegetation type which do fall into the corresponding class. The values for the vegetation types are: -

	Reliability
Type A and B [Very poor]	**0.88**
Type C and D [Poor]	**0.79**
Type E, F and G [Medium]	**0.37**
Type H [Rich]	**1.00**
Type 1 and J [Very rich]	**1.00**

It can be seen from these results that the reliability of the qualitative method of prediction of soil nutrient class is satisfactory with the exception of those vegetation

Figure 8.3.1a
Comparison of indicator values for frequent species

Species (scientific name)	English common name	Number of sites present	Ellenberg R-value	[D]CCA species score	"Revised" R-value
Calluna vulgaris	heather	10	1	180	1.7
Vaccinium myrtillus	blaeberry	20	2	106	2.7
Deschampsia flexuosa	wavy hair-grass	31	2	94	2.9
Luzula pilosa	hairy woodrush	16	5	80	3.1
Galium saxatile	heath bedstraw	21	2	79	3.1
Agrostis capillaris	common bent	28	4	73	3.2
Blechnum spicant	hard fern	10	2	48	3.5
Pteridium aquilinum	bracken	29	3	33	3.7
Oxalis acetosella	wood sorrel	35	4	29	3.7
Dryopteris affinis	scaly male-fern	16	5	29	3.7
Viola riviniana	common violet	19	4	29	3.7
Holcus lanatus	Yorkshire fog	15	no value	14	3.9
Dtyopteris dilatata	broad buckler-fern	49	no value	14	3.9
Holcus mollis	creeping soft-grass	27	2	10	4.0
Digitalis purpurea	foxglove	12	3	8	4.0
Juncus effusus	soft rush	13	3	-11	4.3
Lonicera periclymenum	honeysuckle	17	3	-14	4.3
Ilex aquifolium	holly	13	4	-15	4.3
Anthoxanthum odoratum	sweet vernal-grass	7	5	-19	4.4
Teucrium scorodonia	wood sage	10	2	-21	4.4
Agrostis stolonifera	fiorin	15	no value	-31	4.5
Rubus fruticosus	bramble	52	5	-35	4.6
Rubusidaeus	raspberry	8	no value	-39	4.7
Athyrium filix-femina	lady-fern	14	no value	-40	4.7
Anemone nemorosa	wood anemone	9	no value	-48	4.8
Hedera helix	ivy	18	no value	-59	4.9
Deschampsia cespitosa	tufted hair-grass	18	no value	-67	5.0
Dryopteris filix-mas	male-fern	19	5	-67	5.0
Chamerion angustifolium	rose-bay willowherb	11	5	-71	5.1
Hyacinthoides non-scripta	bluebell	13	7	-78	5.2
Cotylus avellana	hazel	13	no value	-90	5.3
Crataegus monogyna	hawthorn	12	8	-107	5.6
Ajuga reptans	bugle	9	6	-109	5.6
Brachypodium sylvaticum	false-brome	10	6	-127	5.8
Circaea lutetiana	enchanter's nightshade	7	7	-140	6.0
Glechoma hederacea	ground-ivy	9	no value	-167	6.4
Urtica dioica	stinging nettle	7	7	-186	6.6
Stachys sylvatica	hedge woundwort	7	7	-197	6.8
Mercurialis perennis	dog's mercury	7	8	-202	6.8
Galium aparine	cleavers, goosegrass	8	6	-205	6.9

Figure 8.3.1b
Revised indicator values for frequently encountered species

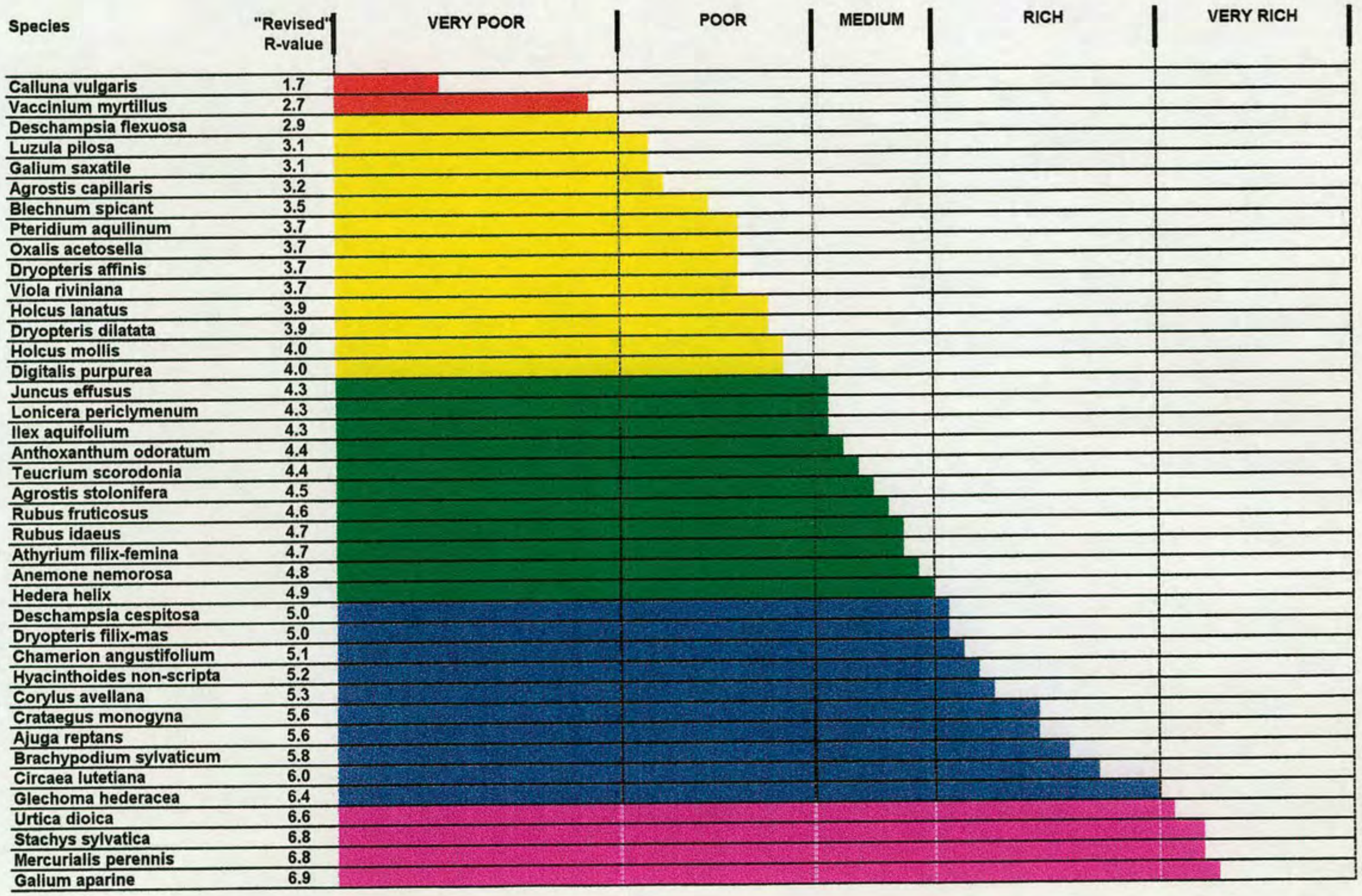
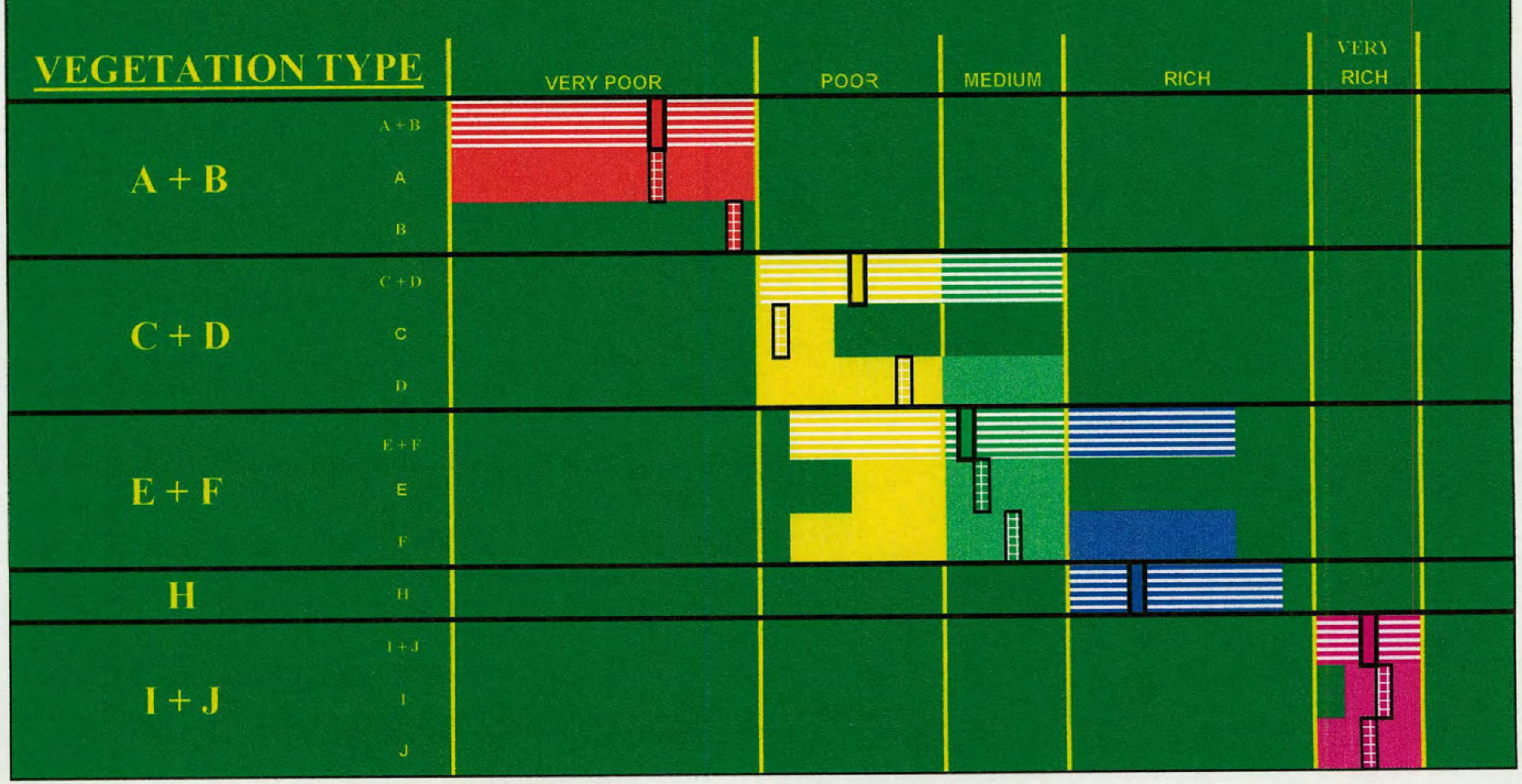


Figure 8.3.2

[D]CCA chemical score ranges and means for visually-dominant vegetation types



types that correspond to the medium soil nutrient class [see Figure 8.3.2.]. The decision as to the location of the poor/ medium soil nutrient class boundary is the most difficult to make as Type D [bracken dominated] grades into Type E [bramble dominated (with bracken)]. This decision also has a major effect on the reliability figures presented for these two vegetation types. In this part of the nutrient spectrum, use of the quantitative method, based on all the species present is essential.

8.4 Exploring the use of humus type as an indicator of soil nutrient regime

Having now produced a scored ordination of the sites and decided upon the basis of its division into soil nutrient classes, it is possible to explore the effectiveness of humus type as a supporting indicator of soil nutrient regime class. The humus types [British Columbian and French systems] set out for the sites in Chapter 4, can be compared with the assigned soil nutrient class of those sites [see Figures 8.4.1.and 8.4.2]

The following key points should be drawn:-

- Most humus types appear to have a broad amplitude in terms of soil nutrient regime. This suggests that soil nutrient regime is only one influence on the development of humus type, alongside factors such as soil moisture regime, soil texture and tree crop species ("litter quality").

- Humus type can only be used to indicate sectors of the soil nutrient regime range, rather than individual classes [with the exception of **eumull** = **very rich**]

- The recognition of a **mor** type is sufficient for the diagnosis of **very poor** and **poor** soil nutrient regimes. There does not seem to be any advantage for this purpose of sub-dividing the type as is done in the British Columbian scheme.

- The recognition of a **moder** type is sufficient for the diagnosis of **poor** and **medium** soil nutrient regimes with reasonable reliability. A more active **mullmoder/ oligomull** type can be used to distinguish the **medium** soil nutrient regime in many cases.

- The French **mesomull** type appears superior in its prediction of **medium** and **rich** soil nutrient regimes as compared with the British Columbian **vermimull** type, which is very plastic as regards soil nutrient regime.

Figure 8.4.1

[D]CCA chemical score range and mean for selected BC humus types

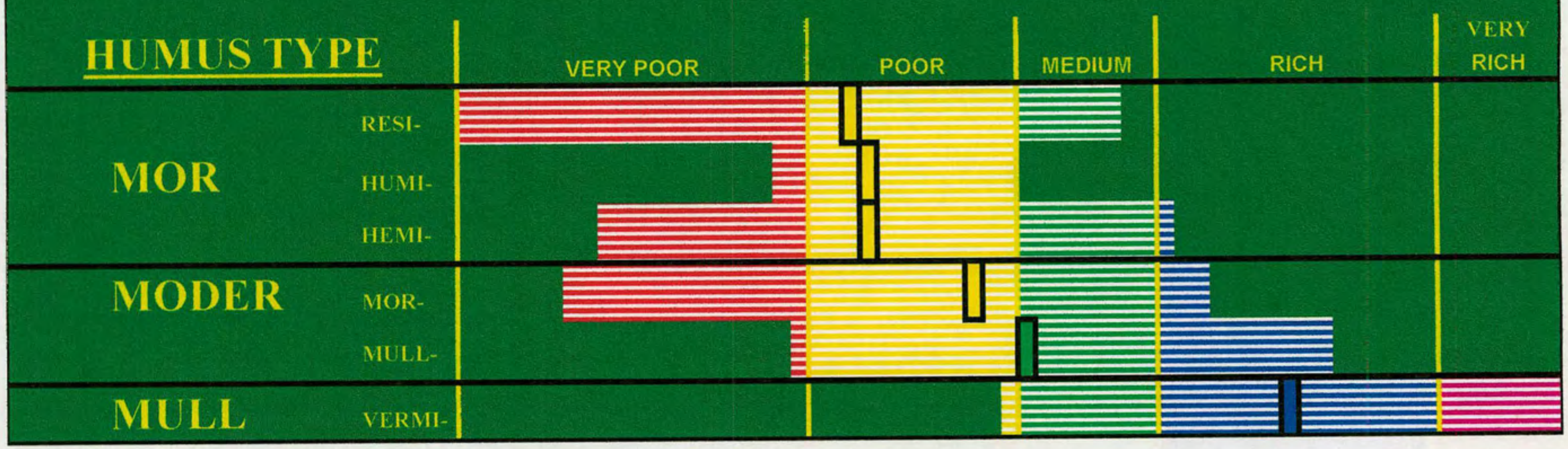
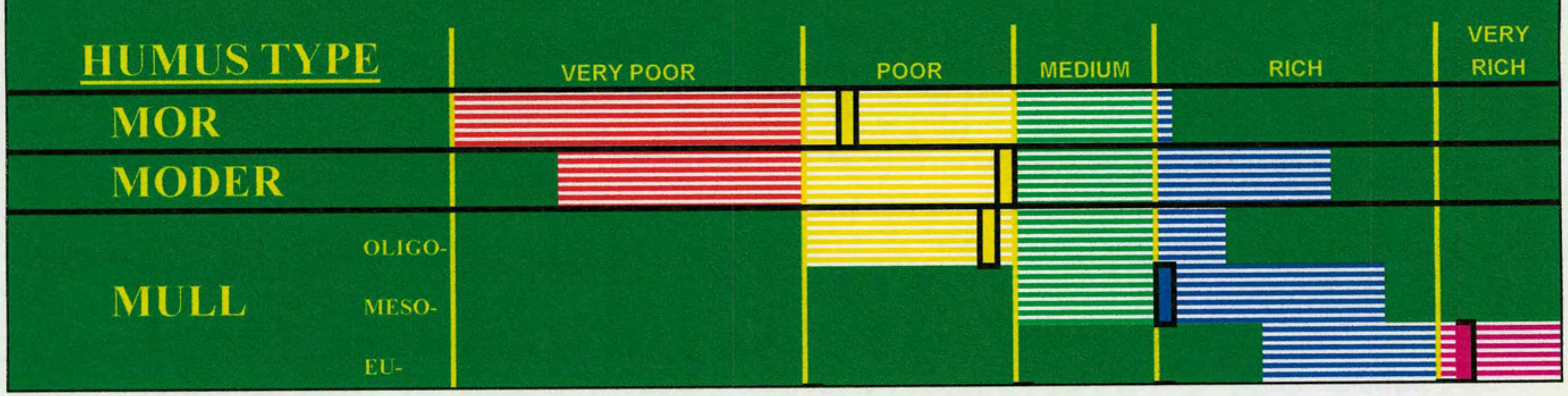


Figure 8.4.2

[D]CCA chemical score range and mean for simplified French humus types



- The French **eumull** type allows the specific prediction of the **very rich** soil nutrient regime.

It appears to be preferable to draw upon the French system of humus form taxonomy, for this specific purpose of soil nutrient diagnosis under British conditions.

The following simplified taxonomy can be envisaged, on the basis of the above, for use in the field in Great Britain:-

UK taxonomy	**BC taxonomy**	**French taxonomy**	**SNR**
Mor [1]	Resimor Humimor Hemimor	Mor	VP-P
Moder [2]	Mormoder Leptomoder	Dysmoder Eumoder Hemimoder	P-M
Oligomull [3]	Mullmoder	Amphimull Dysmull Oligomull	M
Mesomull [4]	Vermimull	Mesomull	M-R
Eumull [5]	Vermimull	Eumull	VR

Suggested visually diagnostic definitions for these classes are provided by Pyatt & Suarez (1997).

8.5 Quantifying the nutrient classes in terms of the individual soil variables

A primary objective of the work leading to this thesis was to quantify soil nutrient regime in British forests. This issue can be examined in two ways (a) the quantification of an aggregate gradient of soil nutrient regime as already presented, or alternatively, (b) the description of the range of conditions encountered in respect of each individual soil nutrient variable determined. The relevant soil analytical data are presented in Chapter 6 and Appendix 4.

Having defined the five classes of soil nutrient regime in terms of an aggregate gradient such as that produced by [De-trended] Canonical Correspondence Analysis, it cannot be expected that the classes will each occupy discrete sectors of the value range for any one chemical determinand. There will inevitably be substantial overlap between the sectors occupied. However, for those determinands which are correlated with the gradient used [all but the measures of ammonium-N and of loss-on-ignition], it would be expected that the centres of gravity of the sectors occupied by each class would reflect this trend. The relevant ranges, medians, means and quartiles are displayed in Figure 8.5.1.

The following features can be observed:-

- Substantial class occupancy overlap does occur for all variables.

- The separation is greatest for the pH, calcium and nitrate-N measures.

- The centroids follow the trend of soil nutrient regime for all the variables that are correlated with it. This is not the case for the measures of ammonium-N and of loss-on-ignition.

- The lower three classes differ mainly in their nitrogen supply, with both base status and nitrogen supply differentiating between the upper three classes.

Key to Figure 8.5.1

pH [H_2O]	pH determined in water for top, middle & base soil layers
pH [$CaCl_2$]	pH determined in calcium chloride for top, middle & base soil layers

For the top 50cm of the soil profile:-

EXT Ca	Calcium extractable in 1M ammonium acetate pH7
EXT Mg	Magnesium extractable in 1M ammonium acetate pH7
EXT K	Potassium extractable in 1M ammonium acetate pH7
TOTAL P	Phosphorus determined in aqua regia digest
AV NO_3:N	NO_3-nitrogen extractable in 1M potassium chloride pre-incubation
MIN NO_3:N	NO_3-nitrogen extractable in 1M potassium chloride post-incubation
AV NH_4:N	NH_4-nitrogen extractable in 1M potassium chloride pre-incubation
MIN NH_4:N	NH_4-nitrogen extractable in 1M potassium chloride post-incubation
L.O.I.	Loss-on-ignition at 500°C

On the charts:-

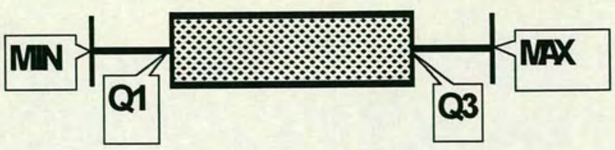
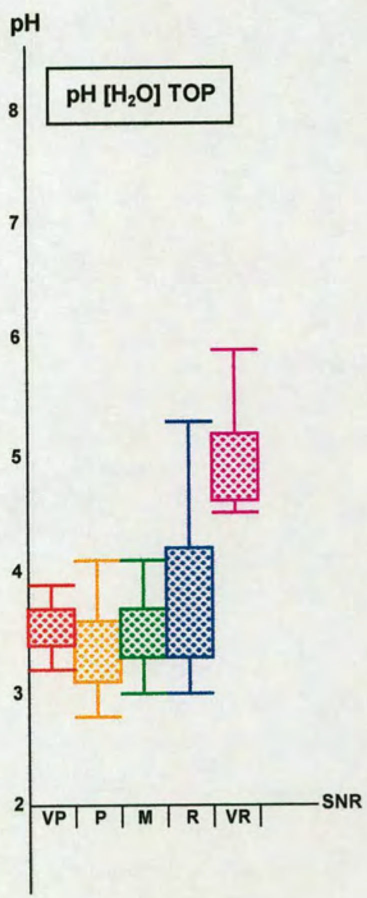
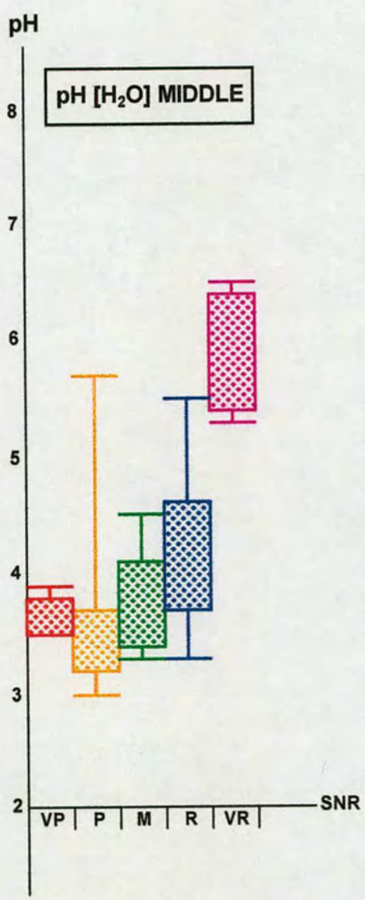


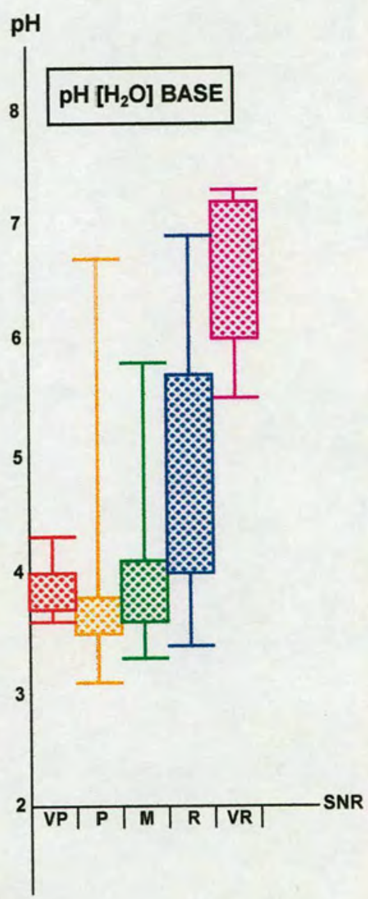
Figure 8.5.1
Individual chemical variable ranges, quartiles and means for each soil nutrient class

	SNR	pH [H2O] [TOP]	pH [H2O] [MIDDLE]	pH [H2O] [BASE]	pH [CaCl2] [TOP]	pH [CaCl2] [MIDDLE]	pH [CaCl2] [BASE]	EXT Ca kg/ha	EXT Mg kg/ha	EXT K kg/ha	TOTAL P kg/ha	AV NO3:N kg/ha	MIN NO3:N kg/ha	AV NH4:N kg/ha	MIN NH4:N kg/ ha	L.O.I. Mg/ha
MINIMUM	VERY POOR	3.2	3.5	3.6	2.8	2.9	3.6	49.0	83.0	113.0	330.2	0.2	1.7	0.0	38.7	98.0
1ST QUARTILE		3.4	3.5	3.7	2.9	3.4	3.9	243.0	102.0	127.5	391.8	1.5	7.0	1.3	51.4	230.8
MEDIAN		3.5	3.7	3.9	3.2	3.5	4.0	296.5	142.0	143.0	627.2	6.1	10.9	6.6	62.2	245.0
MEAN		3.6	3.7	3.9	3.2	3.5	4.0	295.9	139.4	149.0	592.5	7.8	12.4	12.5	78.6	273.8
3RD QUARTILE		3.7	3.8	4.0	3.5	3.7	4.1	335.8	167.0	164.8	718.8	12.3	16.1	15.9	86.4	343.3
MAXIMUM		3.9	3.9	4.3	3.6	4.1	4.3	560.0	212.0	210.0	911.2	19.7	28.5	53.1	182.0	436.0
MINIMUM	POOR	2.8	3.0	3.1	2.8	2.6	2.9	45.0	39.0	56.0	136.4	3.3	0.0	0.7	11.1	117.0
1ST QUARTILE		3.1	3.2	3.5	3.0	3.1	3.6	132.5	82.0	96.0	671.3	6.1	7.4	18.9	70.3	208.5
MEDIAN		3.3	3.5	3.7	3.1	3.5	3.8	215.5	114.5	145.5	1006.8	16.8	18.6	28.8	86.2	259.5
MEAN		3.4	3.5	3.8	3.1	3.4	3.8	644.8	127.0	173.5	1092.1	18.3	25.8	36.2	99.1	266.3
3RD QUARTILE		3.6	3.7	3.8	3.2	3.7	4.0	599.5	143.0	182.3	1391.6	26.1	43.9	51.6	117.5	308.5
MAXIMUM		4.1	5.7	6.7	3.7	5.4	6.4	3740.0	354.0	913.0	2306.3	46.5	89.0	93.1	221.5	532.0
MINIMUM	MEDIUM	3.0	3.3	3.3	2.8	2.8	3.1	197.0	49.0	111.0	729.8	1.2	0.0	0.9	26.6	148.0
1ST QUARTILE		3.3	3.4	3.6	3.1	3.4	3.6	352.0	83.5	137.0	1076.3	18.3	29.3	16.1	65.0	178.0
MEDIAN		3.4	3.6	3.9	3.3	3.6	3.8	469.0	105.0	196.0	1482.2	34.4	62.5	43.5	74.6	206.0
MEAN		3.5	3.8	4.0	3.3	3.6	3.9	1635.2	390.2	243.6	1586.8	33.1	73.0	51.0	89.2	222.5
3RD QUARTILE		3.7	4.1	4.1	3.5	3.9	4.2	1369.0	464.0	262.5	1917.7	44.4	95.9	74.7	113.6	285.0
MAXIMUM		4.1	4.5	5.8	4.0	4.3	5.7	8055.0	2212.0	787.0	3409.4	76.3	247.7	135.5	206.1	321.0
MINIMUM	RICH	3.0	3.3	3.4	3.3	3.5	3.6	222.0	75.0	185.0	517.1	0.0	18.7	0.0	0.0	99.0
1ST QUARTILE		3.3	3.7	4.0	3.6	3.6	3.8	1015.0	302.0	220.0	1047.9	36.0	82.1	10.1	31.8	171.0
MEDIAN		3.5	3.9	4.6	3.6	4.0	4.5	5617.0	393.0	306.0	1488.3	56.7	87.9	27.0	54.8	223.0
MEAN		3.8	4.2	4.8	4.0	4.3	5.0	10870.5	577.8	319.5	1498.5	55.2	102.9	25.4	83.0	219.5
3RD QUARTILE		4.2	4.6	5.7	3.9	4.6	6.5	13260.0	646.0	355.0	1695.8	70.3	111.3	44.4	87.0	273.0
MAXIMUM		5.3	5.5	6.9	5.6	6.7	7.1	39239.0	2078.0	569.0	2510.7	108.8	245.2	50.9	287.9	345.0
MINIMUM	VERY RICH	4.5	5.3	5.5	4.6	4.8	5.2	9639.0	483.0	272.0	1719.4	102.6	167.5	0.0	5.1	181.0
1ST QUARTILE		4.6	5.4	6.0	4.8	5.1	5.7	14559.0	988.8	364.8	2296.3	131.0	260.5	1.4	10.1	247.3
MEDIAN		4.9	5.9	7.1	5.0	5.7	6.8	18270.5	1267.0	586.0	2515.5	139.1	282.5	3.9	96.1	277.0
MEAN		5.0	5.9	6.6	5.1	5.7	6.3	20953.0	1527.3	656.3	2647.7	162.5	266.2	18.7	125.1	301.3
3RD QUARTILE		5.3	6.4	7.2	5.2	6.3	6.8	23487.3	1620.3	802.8	3083.5	178.7	295.8	11.9	180.2	368.3
MAXIMUM		5.9	6.5	7.3	6.2	6.5	6.9	40990.0	3513.0	1328.0	3639.8	274.2	311.1	89.2	363.7	437.0

Figure 8.5.1
Individual chemical variable ranges and quartiles for each soil nutrient class







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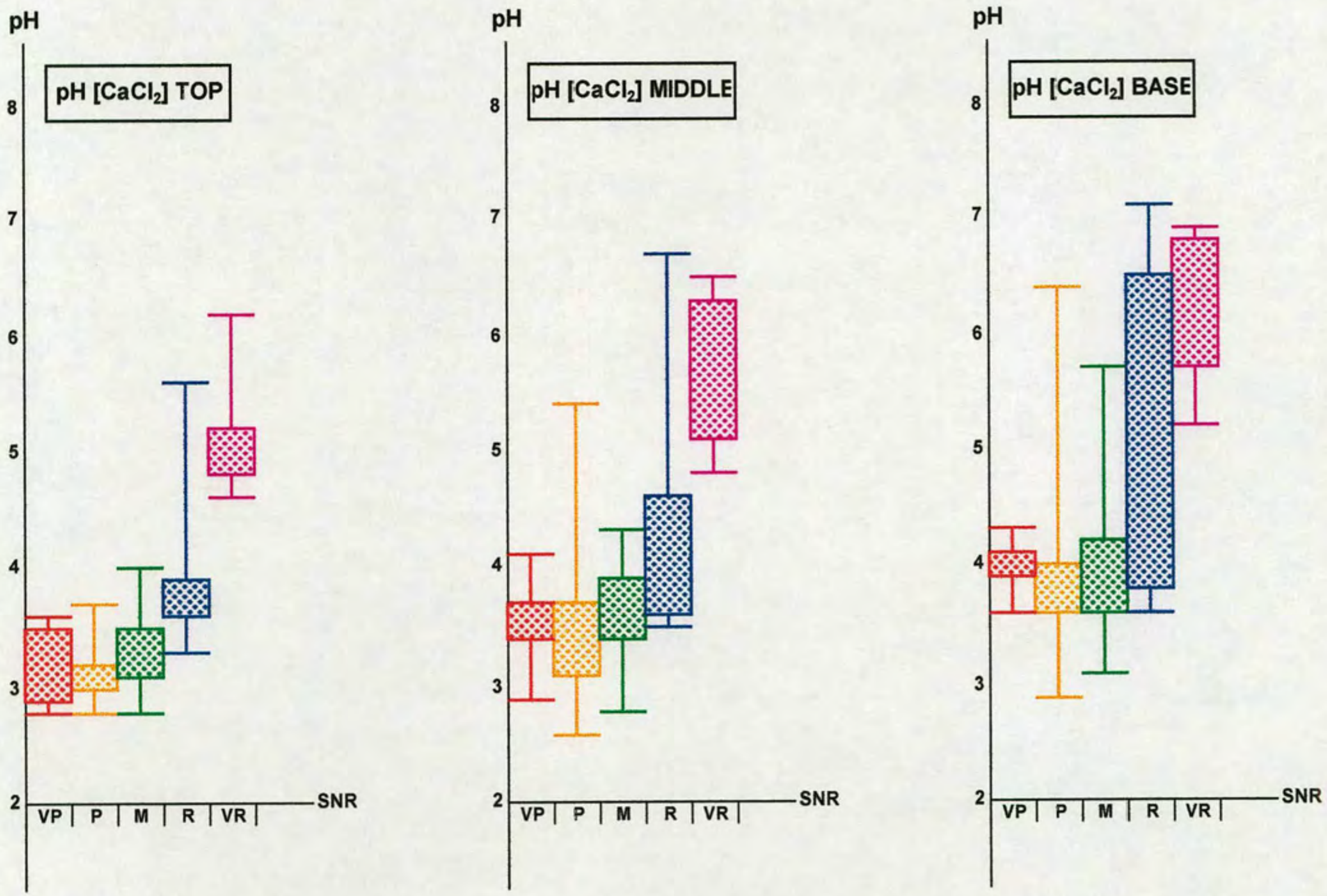
Individual chemical variable ranges and quartiles for each soil nutrient class



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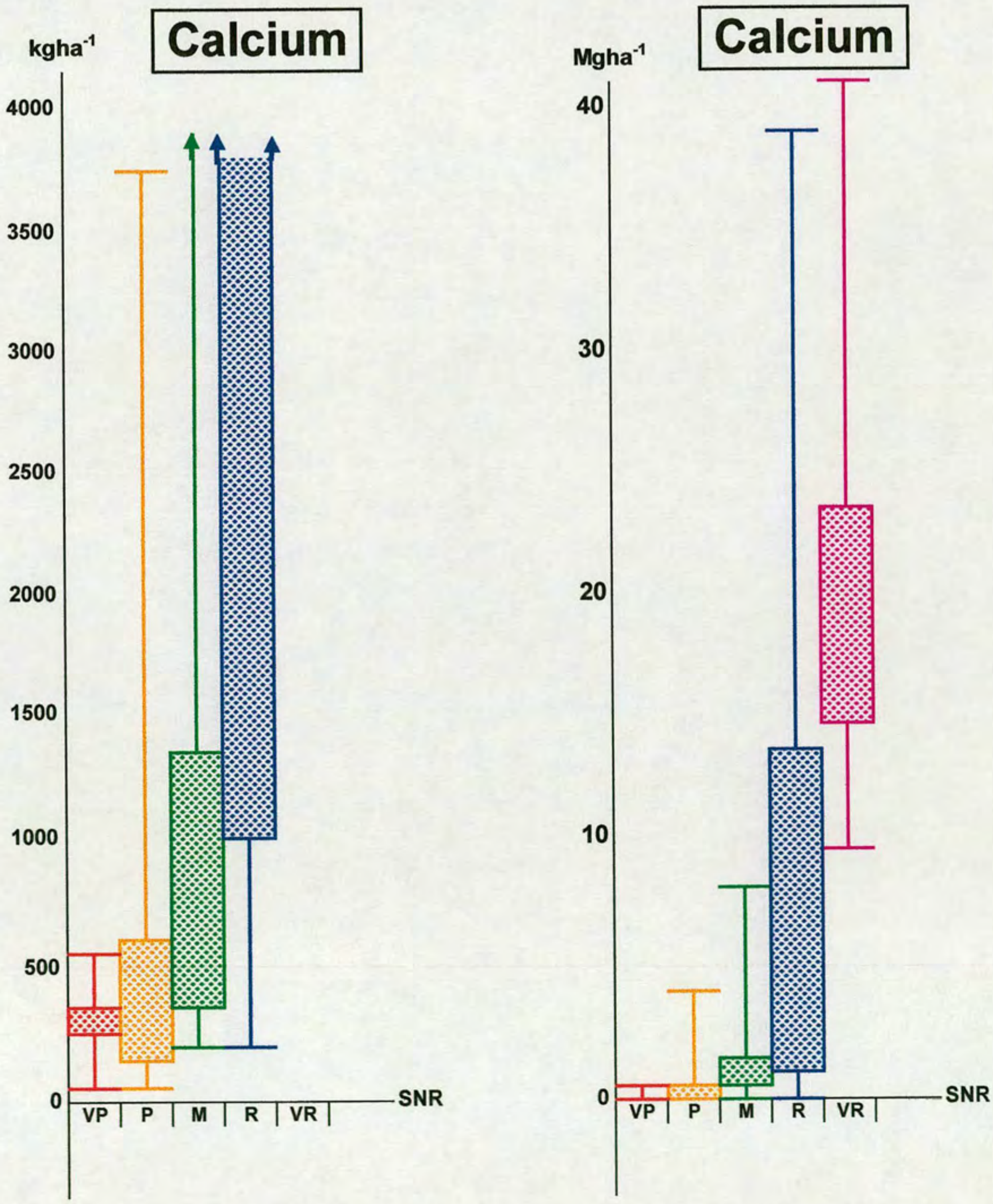

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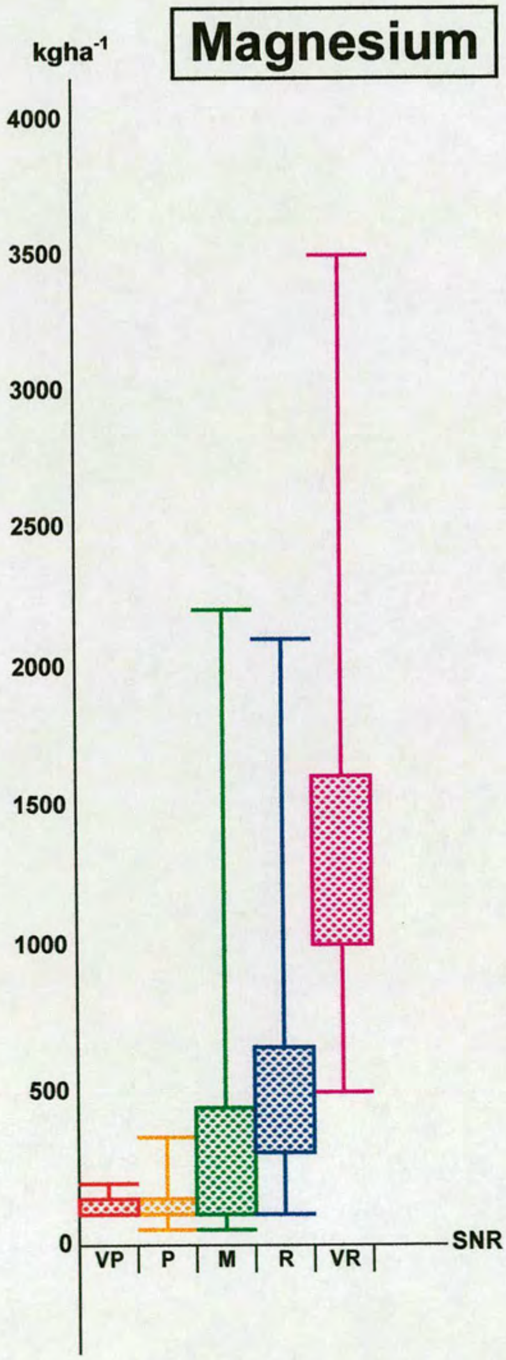

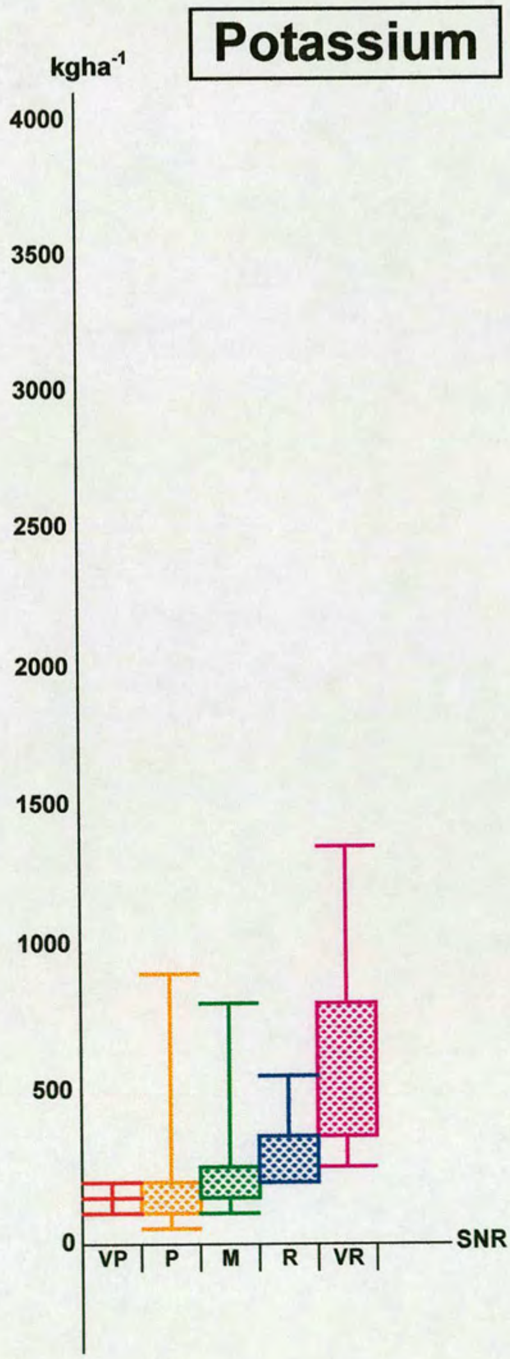

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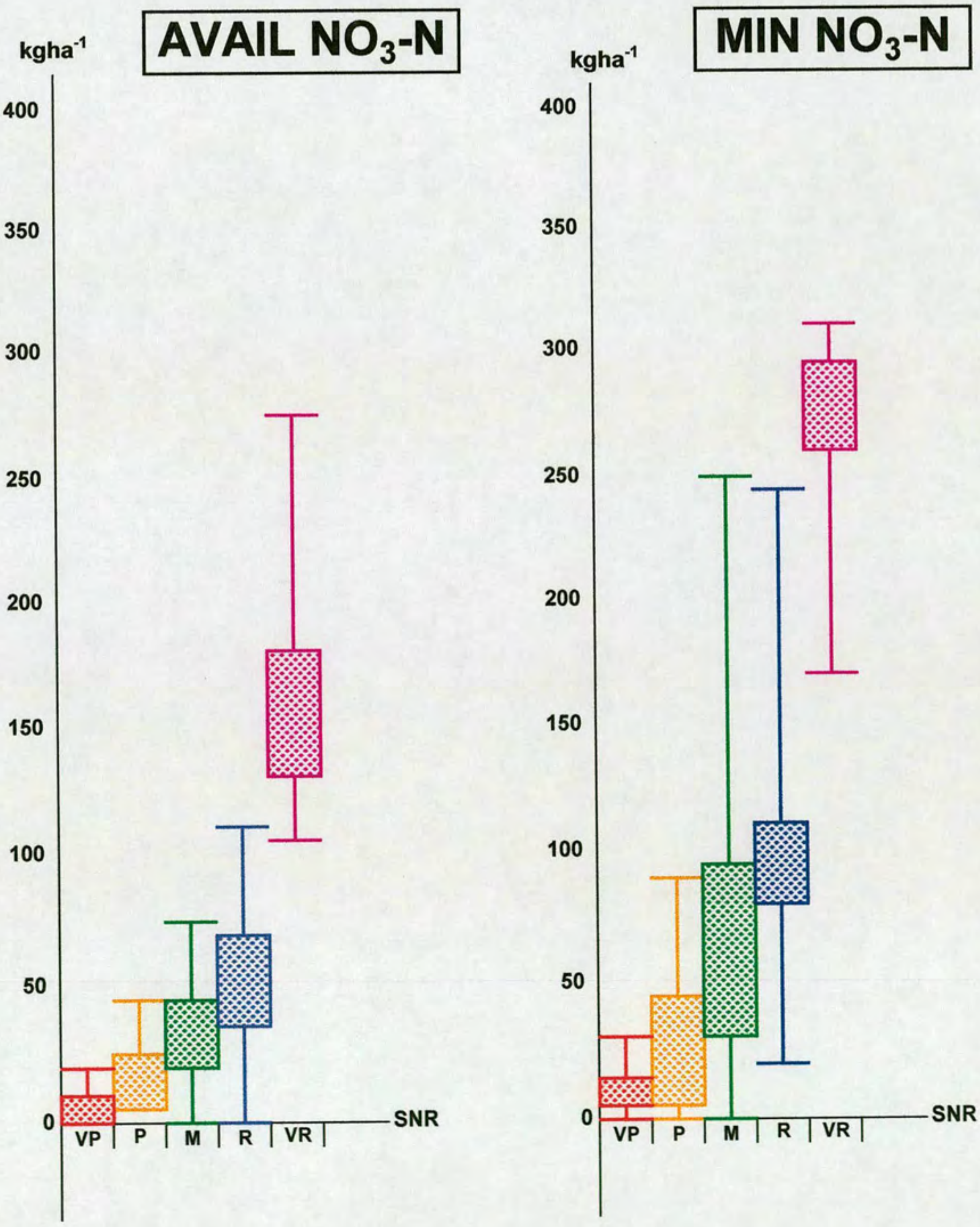


Figure 8.5.1

Individual chemical variable ranges and quartiles for each soil nutrient class

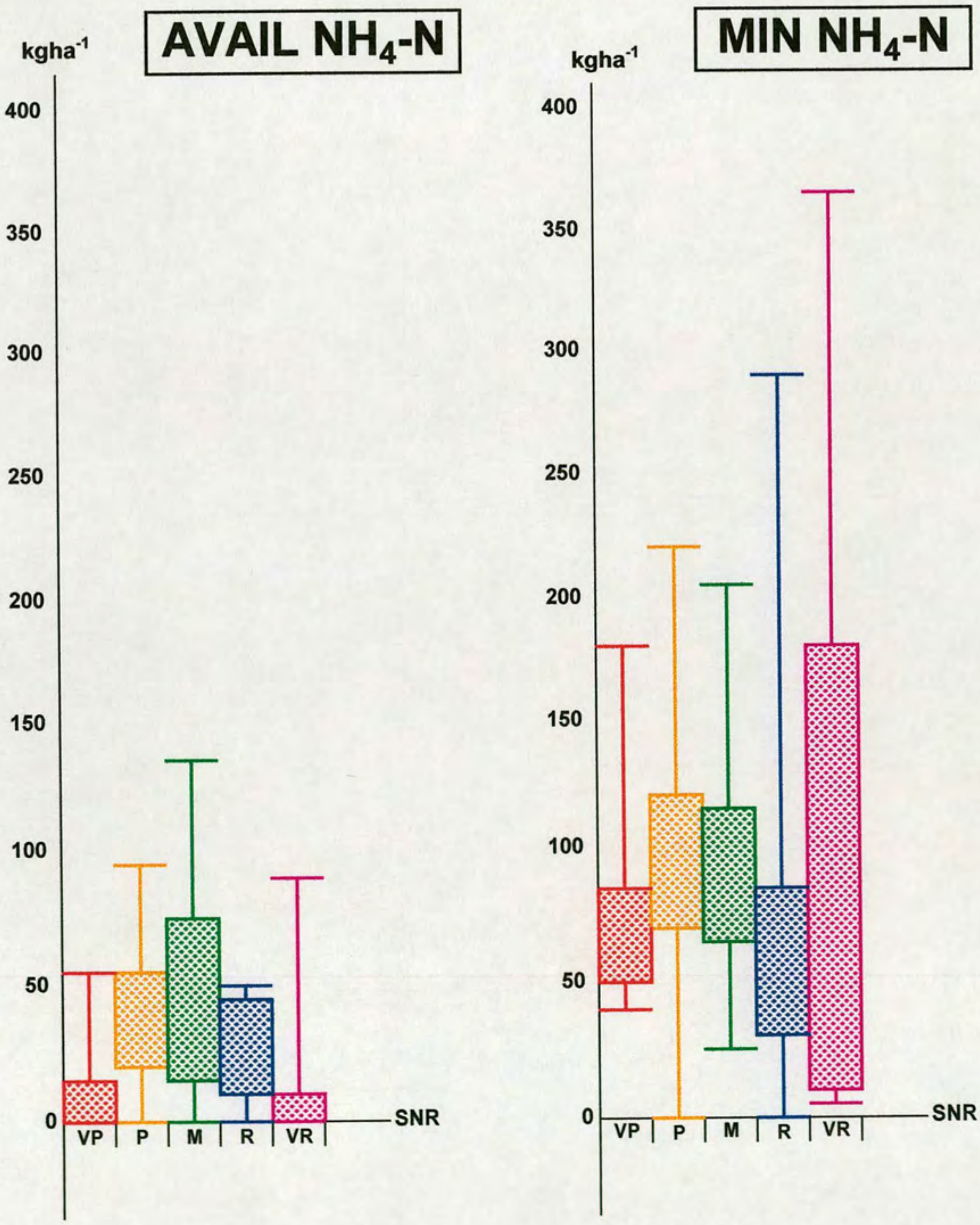
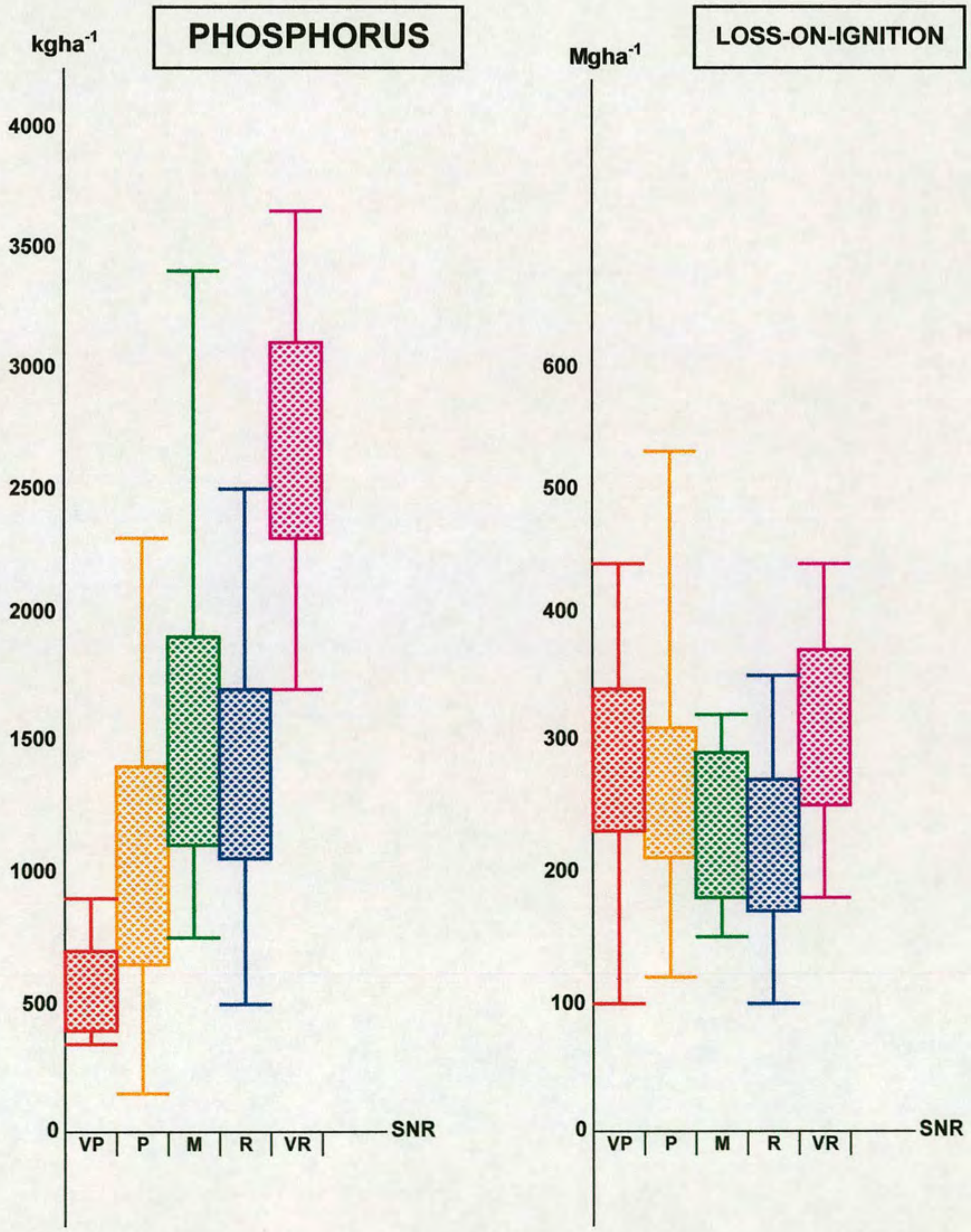


Figure 8.5.1
Individual chemical variable ranges and quartiles for each soil nutrient class



8.6 Relating the distribution of the N.V.C. communities to S.N.R

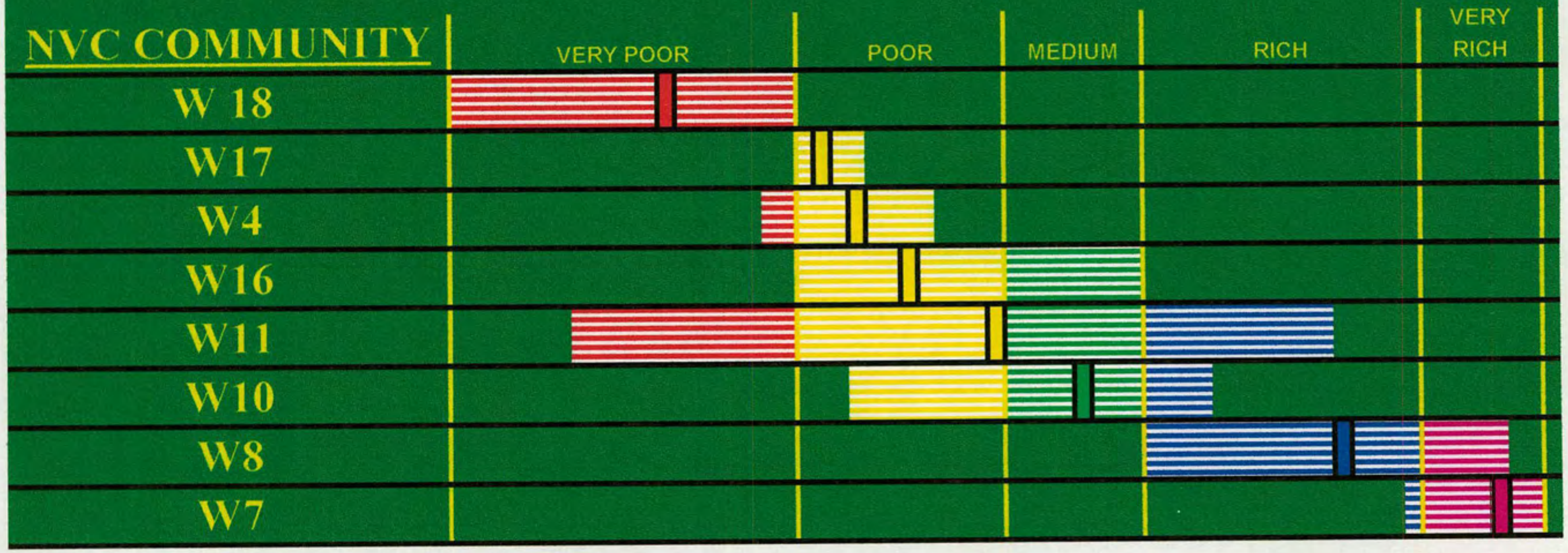
It was also one of the objectives of this research project to examine the extent to which the physical distribution of the woodland communities as defined by the National Vegetation Classification could be related to the soil nutrient regime of the sites on which they are observed to occur.

As the majority of the field-work for this study was conducted in plantation stands of non site-native species, the evidence gathered relates in the first instance to the observed occurrence of the field layer vegetation components of these communities. [Only two of the sites actually carried complete semi-natural woodlands, although a number of the sites carrying mature plantations of *Pinus sylvestris* [L.] or broad-leaves approximated to semi-natural conditions]. Thus the assumption is implicit that the suitability of a site for the ground vegetation component of a community signifies that it would be suitable for the entire community in the absence of the plantation canopy - this may not always be valid, principally for climatic reasons. However it does seem reasonable to assume that the soil nutrient conditions would be suitable for the development of the community all else being equal.

For the majority of the sites sampled it was relatively straight-forward to assign a "best fit" N.V.C. woodland sub-community by comparison with the species lists provided by Rodwell (1991), although in some instances the species diversity of the site was rather low, and the allocation therefore less certain. Figure 8.6.1 shows the ranges of soil nutrient regime occupied by sites with each of a range of N.V.C. community types, based on ground vegetation only [for plantations]. It can be seen that a marked correspondence exists between the N.V.C. sub-communities and their preferred soil nutrient regime. The following sub-community/ soil nutrient class relations are observed:-

Figure 8.6.1.

[D]CCA chemical score range and mean for selected NVC communities and sub-communities



W4	*Betula pubescens* woodland with *Molinia caerulea*	**Poor**
W7	*Alnus glutinosa - Fraxinus excelsior* woodland with *Lysimachia nemorum*	**Very rich**
W8	*Fraxinus excelsior - Acer campestre* woodland with *Mercurialis perennis*	**Rich**
W10	*Quercus robur* woodland with *Pteridium aquilinum and Rubus fruticosus*	**Medium [Rich]**
W11	*Quercus petraea - Betula pubescens* woodland with *Oxalis acetosella*	**Medium [Poor]**
W14	*Fagus sylvatica* woodland with *Rubus fruticosus*	**Rich**
W16	*Quercus* spp.-*Betula* spp. woodland with *Deschampsia flexuosa*	**Poor**
W17	*Quercus petraea-Betula pubescens* woodland with *Dicranum majus*	**Poor**
W18	*Pinus sylvestris* woodland with *Hylocomium splendens*	**Very poor**

As was observed for the visually-dominant vegetation types, the fidelity of these relationships is much greater for those communities occurring at either end of the nutrient range. Communities W10 and W11, although centred in the medium soil nutrient class, also extend into the poor and rich classes to a considerable degree. This essentially highlights the wide ecological amplitude of a small group of species characterising these communities [mainly *Pteridium aquilinum, Rubus fruticosus, Dryopteris* spp. and *Oxalis acetosella*].

These results reflect the findings of another mode of analysis of the soil nutrient preferences of the N.V.C. woodland sub-communities [Pyatt (1995)], which relies on assigning Ellenberg R and N values to the species listed by Rodwell (1991) as characterising them. This allows a frequency-weighted sub-community mean Ellenberg indicator value for soil nutrient regime to be calculated.

The W9 community was surprisingly not encountered at any of the sites studied, and so cannot be related to soil nutrient regime at present.

8.7 <u>Analysing the relationship between tree yield and S.N.R.</u>

As discussed in Chapter 3, it was considered desirable to conduct a small exercise in site-yield comparison, using the mensuration data held for the stands occupying the sites studied and the soil nutrient scores for those sites emerging from this present project.

As this exercise was only intended to be a subsidiary element of the work, the selection of sites was not designed to allow the effects of soil nutrient regime on yield to be readily isolated from other influences. Hence, for any one crop species, the sites vary markedly in soil moisture regime and in climatic regime, both of which are expected to have a significant impact on yield.

Sufficient sites had been studied for three crop species to allow such a comparison to be made with some chance of success. For *Pinus sylvestris* 15 sites were studied, for *Quercus* spp. [L.] 12 sites and for *Larix* spp. [Miller] 15 sites. [in the latter case it was decided to restrict the comparison to the 11 sites stocked with *Larix kaempferi* [(Lindley) Carriere]]. See Figure 8.7.1. A simple linear modelling approach was adopted. The following results were obtained:-

Figure 8.7.1
Comparison of [D]CCA chemical score with general yield class for selected sites

Site code	Species	[D]CCA score [chemical]	G.Y.C. [SP]	G.Y.C. [JL]
ABF1	SP	4.87	8.00	
ABF2	JL	3.60		9.30
BAL1	SP	3.47	10.30	
CER1	JL	3.51		10.00
DEN7	JL	5.11		13.90
DOW1	SP	5.57	13.40	
DOW3	SP	4.45	12.60	
DOW4	SP	4.96	16.60	
INV1	SP	3.11	10.60	
KCD1	JL	4.11		8.20
LAK1	JL	5.42		10.00
LCH 1	JL	3.60		10.00
LOT2	JL	4.79		11.40
LWT1	SP	3.49	11.10	
MID1	SP	4.85	13.10	
MOR2	SP	2.36	2.70	
NEW1	SP	4.64	11.60	
SEA1	SP	1.00	7.20	
SEW1	SP	3.64	7.50	
SWD3	JL	4.40		7.90
SWP2	JL	4.74		11.00
SWP3	JL	5.66		13.50
TAY1	JL	5.06		12.50
THT1	SP	5.34	13.00	
THT2	SP	4.19	7.50	
THT4	SP	5.87	11.40	

Key to Figures 8.7.1 to 8.7.3

G.Y.C = General Yield Class
SP = Scots pine
JL = Japanese larch

■ Site data points

Regression model

Figure 8.7.2
[D]CCA soil nutrient score v. General Yield Class for Scots pine
r = 0.65

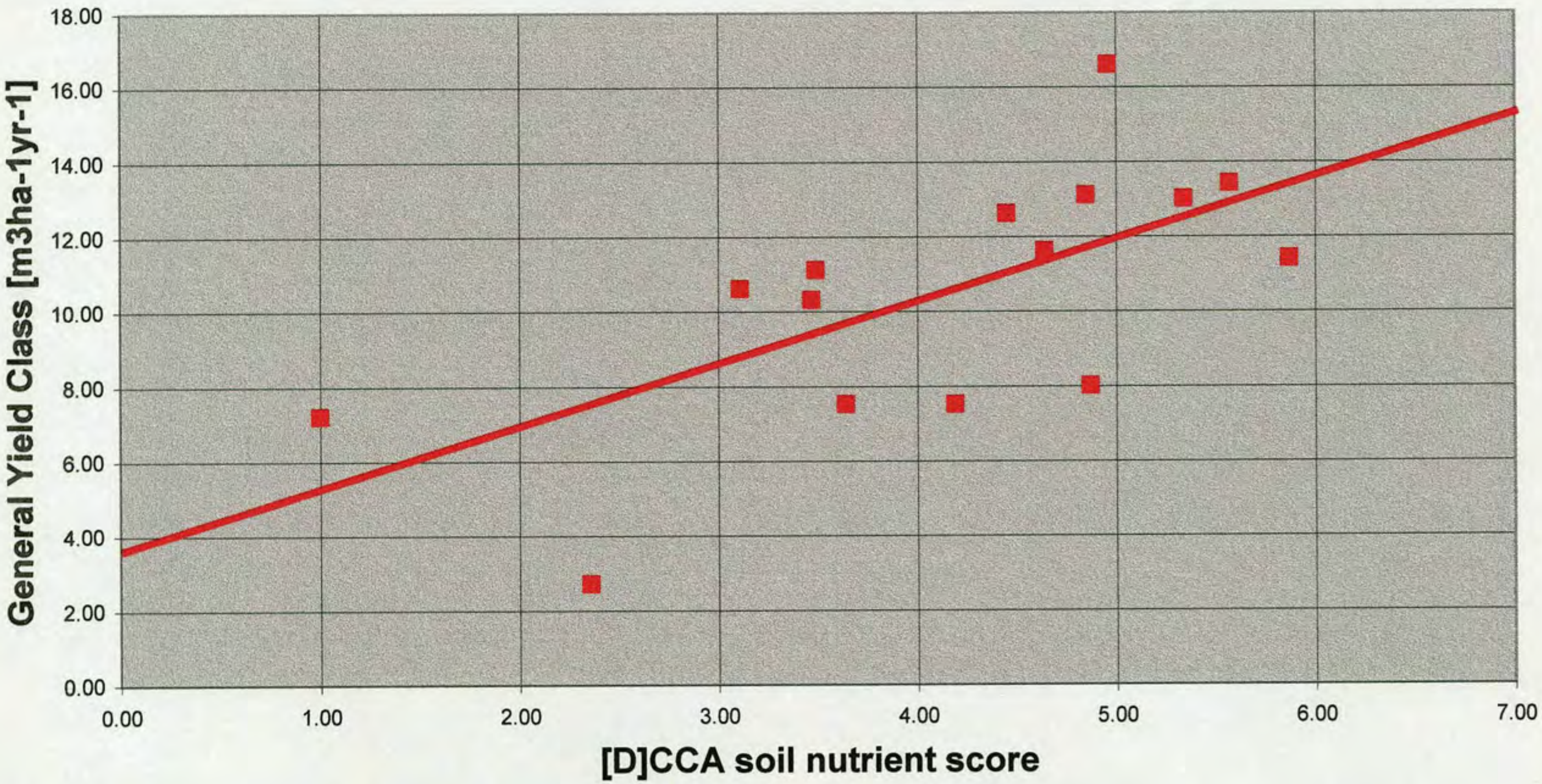
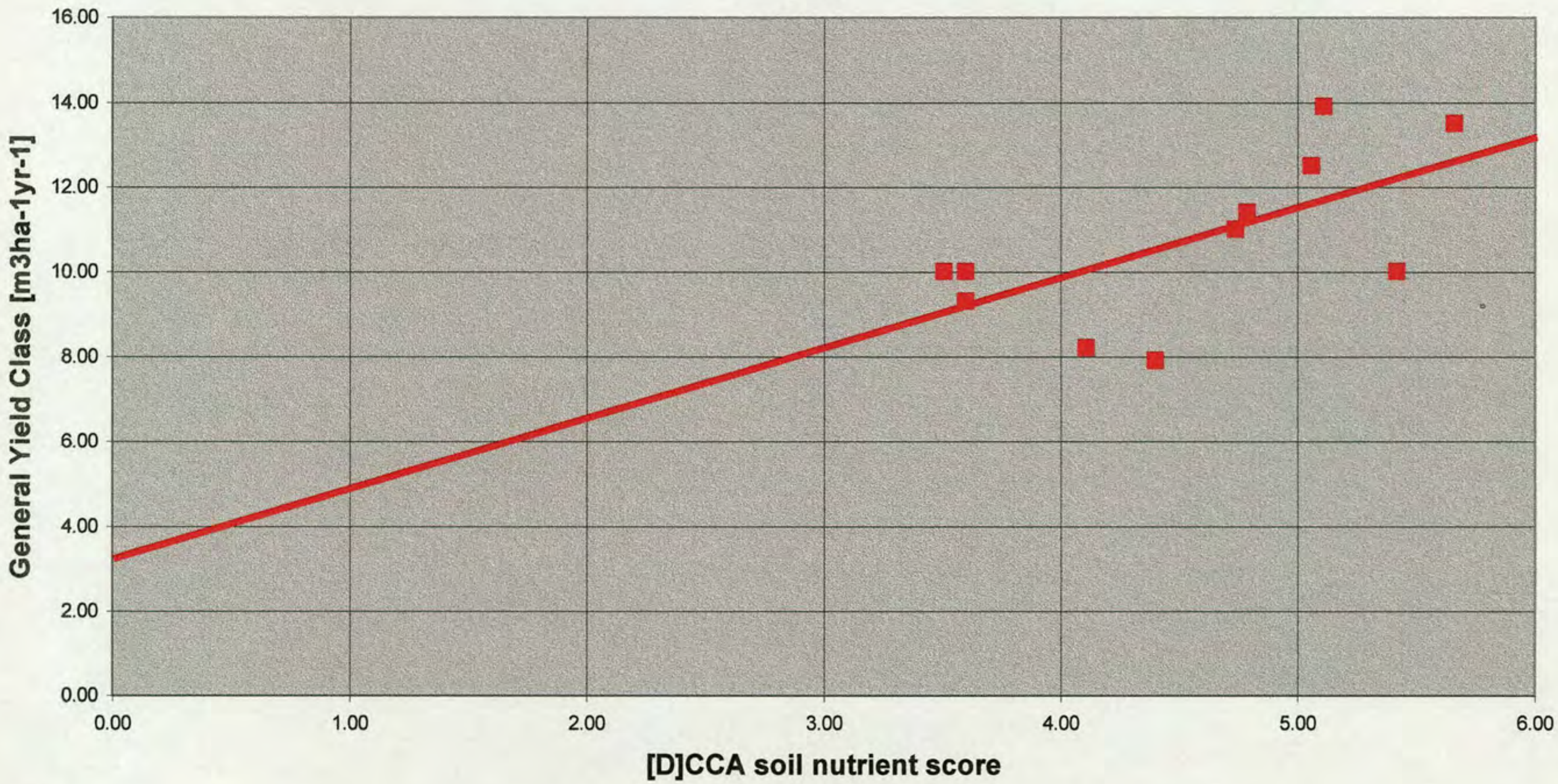


Figure 8.7.3
[D]CCA soil nutrient score v. General Yield Class for Japanese larch
r = 0.64



Pinus sylvestris :	Yield = 1.691 (SNR score) + 3.472	**[r = 0.65]**
Larix kaempferi :	Yield = 1.680 (SNR score) + 3.062	**[r = 0.64]**
Quercus spp. :	No correlation	

Yield was defined as the General Yield Class. This was obtained to a precision of one decimal place for the Permanent Sample Plots, but could only be obtained in the standard bands of 2 $m^3ha^{-1}yr^{-1}$ for the non P.S.P. sites. Insufficient sites were sampled for any other species to permit such a comparison to be made for these.

The relationships obtained for *Pinus sylvestris* and *Larix kaempferi* are interesting, given the nature of the data involved, and are notably similar [see Figures 8.7.2 and 8.7.3]. Whilst the correlations are only moderately strong for this sample, there is certainly some basis for believing that soil nutrient regime influences yield for these species. There is little surprise in the lack of a relationship for *Quercus* spp. for this sample, as these species have a narrow range of General Yield Class.

8.8 Appraisal of methods applied and identification of scope for future work

The methods adopted within this study have broadly fulfilled the general requirements identified in Chapter 1. Chapter 9 will set out formally the contribution which the work has made to the four specific objectives of the Ph.D. study, and will consider its implications for the further development of the Ecological Site Classification scheme for Great Britain.

The primary objective here is to consider whether the methods selected were appropriate and secondly to identify areas where future work is required or desirable.

Site selection [ref. Chapter 3]

The 70 sites studied have proved to be relevant to the requirements of the present work. However, it must be recognised that the specific selection of these sites might influence the relationships which emerge from the statistical analyses described in Chapter 7, and hence the pattern of the classification presented in the present chapter. Whilst most of the important soils and vegetation complexes encountered in British forests were sampled, inevitably some were not, and these are clearly not reflected in the outcome of the work at present. Additionally, the intensity of site sampling was not uniform across the spectrum of soil nutrient regime, as recognised in Chapter 3. These issues will be addressed by further sampling work in the future, using similar methods, with the objective of refining the soil nutrient gradient and its classification once in operational use.

The possible sixth "carbonate" class of soil nutrient regime has not been adequately sampled within this study, and hence cannot yet be quantified in terms of soil chemical variables. This was largely due to the lack of suitable sites [at which to sample this class of soils], within Forestry Commission forests. Observational evidence has been obtained for this class of sites in private woodlands in Great Britain, (especially in the Cotswold beech-woods [Wilson (1997)]), confirming that they are worthy of future study. It is suggested that this is undertaken, in a manner similar to the present study, to complete the quantification of the full range of soil nutrient regimes in British woodlands. This soil nutrient class is recognised to be of greater importance in Continental Europe.

The need, in site selection, to have well developed ground vegetation acted to restrict the sampling of sites in upland conifer forests on poor, wet soils [peaty gleys and thin iron-pan soils], where ammonium-N levels may emerge to be significant. Future work on these important site types would emphasise the use of humus and possibly of bryophytes in soil nutrient regime diagnosis. Sampling would be carried out in further mature stands of the sort used in this study, and also on suitable unforested sites.

It would be valuable to study soil chemistry, ground vegetation species composition and humus type directly for the N.V.C native woodland communities. This might involve sampling native woodland sites such as those used by Rodwell (1991) and co-workers in the evolution of the N.V.C.

The small amount of work described on the relation of tree crop yield to soil nutrient regime, as defined on the new basis evolved by the present study, produced results suggesting that this is a promising line of approach. Its exploration on a more comprehensive basis would require the design of a sampling programme that allowed the yield influences of climate and of soil moisture regime to be screened out of the regression analysis. This should be considered in the planning of future work by the Forestry Commission Mensuration Branch. In particular, the set of soil nutrient determinands selected for this present work should be adopted in future site-yield studies [with soil pH, extractable calcium and nitrate-N measures being indispensable].

Soil sampling and analysis [ref. Chapters 4 and 6]

The techniques of soil sampling and laboratory analysis adopted for this work have proved to be generally effective. The following points should be considered for future adoption:-

- The powered-corer method of volumetric sampling proved capable of producing reliable results. The inherent determination of bulk density is a significant advantage, considered to outweigh the physical demands of using the equipment in the field.

- The expression of soil chemical variables on a spatial basis to a given depth should be considered for adoption alongside mass-fraction expressions. Sampling to a depth of 50cm has proved suitable for British forest conditions.

- The storage of analytical soil samples at refrigerated temperature proved appropriate for the purposes of this work, and is recommended to workers intending the same nutrient analyses for soil nitrogen availability.

- The use of the mineral measures of soil nitrogen produced an effective diagnosis of availability. The nitrate-N component appeared more important in explaining the vegetation impacts of soil nutrient regime for the particular set of sites studied, which suggest the advantage of future use of the aerobic incubation technique.

- The use of a plant available measure of forest soil phosphorus was not found to be effective. It is conceivable that future work might proceed directly to a "total phosphorus equivalent" method, as was adopted later in this present study.

- The description of humus form using both British Columbian and French systems should be completed in the field. The assignment of classes within the French system is more difficult when a physical sample of the humus is not available for close inspection.

Vegetation sampling [ref. Chapter 5]

The methods of vegetation sampling and description employed for this project appear to have performed satisfactorily. The survey season could not have been significantly extended, if the full range of vascular ground vegetation species were to be effectively sampled. There is scope for future work to examine the potential role of bryophytes as soil nutrient indicators - this would obviously require the sampling description to be extended to include these. In most forest conditions a 2 x 2m quadrat size would remain suitable for this purpose. The identification of vascular species posed no significant difficulties, although the grasses presented an initial challenge. It is to be expected that the inclusion of bryophytes would prove more demanding.

The calculation of the abundance-weighted site mean Ellenberg indicator value as an initial mode of assessment of the vegetation proved useful, despite Ellenberg species values having been developed in Central European conditions, and by fairly subjective means. This allowed a site indicator value for soil nutrient regime to be estimated prior to detailed statistical analysis, and hence aided the planning of the ongoing sampling programme. The decision to carry out the weighting on the basis of species cover abundance reflected experience in the pilot study [Hawkes, Pyatt & White (1997)], where it was found to be more reliable than frequency-based weighting. However it does have the effect of placing strong emphasis on the indicative potential of the more abundant species. Whilst this may be advantageous for the practical application of the site classification, it might also be valuable to examine the potential of Domin score weighting for inclusion in future work.

The application of the National Vegetation Classification to the ground vegetation in plantation stands [including many of exotic species], proved more effective than might have been expected, given that this classification was principally designed for use in native semi-natural woodlands. Nonetheless, there are some ground vegetation types encountered frequently in plantations which must be considered at best drastically de-pauperate variants of the corresponding N.V.C. sub-communities [especially those dominated by *Pteridium aquilinum* and/ or by *Rubus fruticosus]*. For this reason it was decided to define the "visually-dominant vegetation types" of plantations independently, despite their emergent inter-connection with the N.V.C. woodland community types. The observed occurrence of the ground vegetation components of the N.V.C woodland communities in association with particular ranges of soil nutrient regime provides evidence that it influences the distribution of the complete assemblages as semi-natural woodlands. However, further work is required, along the lines already suggested, to sample the soil nutrient regime directly for a full range of native woodlands.

Statistical analysis [ref. Chapter 7]

A wider range of multi-variate statistical techniques were applied in this study than in some previous comparable pieces of work. The intention was to "illuminate the soil nutrient complex from a number of angles" . As such, each approach yielded valuable insight in its own right to which was added the mutual benefit of cross-confirmation. The Principal Components Analysis was effective in highlighting the key soil nutrient discriminants between the sites. The two canonical techniques were effective in exploring the relationships between ground vegetation species composition and the individual soil nutrient variables.

It should be recognised however that the outcome of all multivariate statistical analysis is the product of a series of decisions on which variables to measure, which to include in the analyses, which analyses to use and how to conduct them. The selection of soil chemical determinands has been discussed above. The fact that many are inter-correlated might influence the outcome of the multivariate analyses, by a co-linear reinforcement effect. This could carry the risk of distorting the major soil nutrient gradient that is illuminated by the analyses. In this context it is informative that the major component of variation from unconstrained factor analysis strongly reflects this soil nutrient gradient. This analysis does not incorporate the soil chemical data at all, and thus cannot be influenced by any co-linearity therein. The selection of data transformations and, for Principal Components Analysis, of the matrix upon which to carry out the analysis, also have the potential to influence the outcome, and this should be borne in mind when interpreting the results of multivariate analyses. In future work additional multivariate techniques and variants could be considered for application, which might provide further insights into data structure.

9. IMPLICATIONS FOR ECOLOGICAL SITE CLASSIFICATION [E.S.C]

This final chapter will present a concise review of the implications of the work reported in this thesis for the future development and implementation of the Ecological Site Classification.

9.1 Quantification of soil nutrient regime

As indicated in Chapter 1, the primary objectives of the research work leading to the presentation of this thesis were:- (a) the quantification of the range of soil nutrient regime in British forests, and (b) the proposal of a suitable basis for its division into classes for operational use.

It is recommended, as a result of this work, that the definition of soil nutrient regime, to be used as the basis for the classification, should be that linear combination of soil chemical variables which describes the first axis of [De-trended] Canonical Correspondence Analysis on the 70 sites studied.

The value of this linear combination, for a site not included in this study, can be assessed quantitatively by two means:-

- By conducting soil sampling and analysis for that site after the methods of this study, and utilising the soil nutrient data thus obtained in the formula defining the linear combination of soil chemical variables.

- By conducting sampling of the ground vegetation for that site after the methods of this study, and calculating an abundance-weighted site mean indicator value.

It is recommended that the gradient of soil nutrient regime, represented by the linear combination of chemical variables identified above, should be divided into five classes of soil nutrient regime, to be known as "very poor", "poor", "medium", "rich" and "very rich". In Chapter 8 it is suggested that the basis for that division should be those value ranges which correspond best with the occurrence of the visually dominant vegetation types. This will assist in the use of the qualitative mode of soil nutrient regime assessment, using these subjective types. It is likely that the definitions of the class boundaries will continue to be refined in the light of future sampling work.

For the individual soil chemical variables, the ranges and mean values displayed by those of the 70 sites falling within each proposed soil nutrient class are displayed in Figure 8.5.1.

9.2 Use of ground vegetation for soil nutrient regime assessment

It has been shown that ground vegetation can be used effectively to assess nutrient regime in British forest soils. This supports its intended application within the Ecological Site Classification.

The principal mode of use of the ground vegetation for this purpose is the calculation of an abundance-weighted site mean indicator value, which predicts site position on the selected soil nutrient gradient. The species indicator values used should, in the first instance, be those given by Ellenberg (1988) for "R" (soil reaction). For a set of frequently encountered species it is feasible to produce "revised" indicator values, as discussed in Chapter 8. Future sampling work may extend the number of species for which these revised indicator values can be calculated. These can then be used to produce a soil nutrient assessment based on the common species, which can be compared with that produced using Ellenberg "R" values. It may eventually be possible to use the revised values, together with Ellenberg "R" values for the less common species, to produce a combined assessment. However, this would require a compatible scale on which the two sets of values could be related.

A secondary mode of soil nutrient regime assessment utilises the recognition of subjective "visually-dominant vegetation types" as described in Chapters 3 and 8. This method should be used for initial estimation or confirmation only, and not in place of the primary, quantitative method described above.

9.3 Use of humus type for soil nutrient regime assessment

The survey results presented in Chapter 4 and discussed in Chapter 8 suggest that soil nutrient regime influences the development of humus types in British forests. This allows humus type to be used for the qualitative assessment of soil nutrient regime. It may be particularly useful in situations of reduced light availability and sparse ground vegetation. However, its indicative precision is not especially great, and it cannot offer results comparable with those from the quantitative use of ground vegetation. It should be considered, rather, as an approach comparable with the qualitative use of ground vegetation, and may offer helpful corroboration to the findings of the latter.

A suitable simplified typology of humus forms for use within the Ecological Site Classification scheme is proposed in Chapter 8.

9.4 Examining the N.V.C. communities in terms of soil nutrient regime

It has been shown that the occurrence of the National Vegetation Classification woodland communities [or variants thereof], as the field layer vegetation in British plantation forests is related to soil nutrient regime. This relation is most distinct at either end of the spectrum of soil nutrient regime, and less so for those communities primarily associated with mesic regimes.

This evidence provides support to that of indicator species analysis applied to the sub-community species lists as presented by Rodwell (1991). Hence it is possible to define sectors of the soil nutrient range which may be suitable for the establishment of particular N.V.C. communities.

This information will be combined with the outputs of the climatic and soil moisture components of Ecological Site Classification in producing site-specific advice for native woodland creation and management.

9.5 Considerations relating to training and supporting documentation

The implementation of Ecological Site Classification, and in particular its soil nutrient regime assessment methodology, will require an appropriate programme of training and user support.

The primary implication of the work reported herein is to emphasise the need for users to become competent in the identification of forest ground layer vegetation species. Familiarity with a list of 150 - 200 species is likely to allow a user to be confident in applying the system in most forest contexts. Of these 40 - 50 should be considered the key species which are likely to set the range of the site score for most sites, and thus should be known thoroughly. Infrequent species can always be referred to an illustrated Flora for identification. In any particular geographical area there are likely to be a few species of local significance that should be added to the above requirement. These requirements should be compared with the levels of plant identification skills possessed by some forest site specialists in Continental Europe, which can exceed 2000 species.

Alongside these botanical requirements, there will be a need for field users of the system to be able to recognise soil types and describe soil profiles according to the standard methodology. This should pose less difficulty as existing levels of familiarity are likely to be higher, and the process can more readily be broken down into steps. The extension of these skills to humus types may, however, be more challenging, as many of the observational features are rather subtle. For this reason the humus form typology suggested in Chapter 8 is substantially less sophisticated than those applied in countries where a more established expertise in this regard exists.

Experience of the introduction phase of comparable systems of site classification overseas suggests several approaches that have aided their implementation by field staff. Above and beyond the organisation of training courses and seminars covering the above field skills, it has usually proved to be desirable to foster the development of a network of "regional advocates" of the system, who can provide a slightly more advanced level of interpretation than is expected of mainstream users. These individuals usually emerge due to personal interest, but it is helpful if they have established credibility in their respective territories, which will help to overcome some of the perceived novelty of the system. The role of these "advocates" is not to become specialists to be called on to implement the system themselves, and thereby avoid the need for field staff to become familiar with it. Rather they should act as a combination of salesperson and trouble-shooter. It is usually essential that a central point of contact remains to provide an ultimate back-up source of advice about the application of the system. This individual should ideally have been closely involved with the development of the system. Without such an "anchor-point" role being fulfilled, there can be a tendency for the system to lose coherence and develop incompatible regional variants over time.

It has generally been found that spatial tools emerging from the implementation of the system, such as Geographical Information System maps of soil properties and vegetation types, are readily appealing to field users. However, these should not be emphasised at the expense of the field-craft required to conduct self-assessment of individual sites. It is unlikely to be feasible to conduct an extensive survey programme aimed at creating national map coverage from the outset, and site by site application will remain the main way forward.

9.6 Ecological Site Classification in a European context

Coincident with the development of Ecological Site Classification system for Great Britain, a working group has been examining the potential for correlation of the various systems of ecologically-based site classification in use throughout Europe.

This has been undertaken through the mechanism of a European Union Concerted Action, involving key experts from the various member states. The relevant national approaches to forest site classification have been summarised in Chapter 2. The intention has not been to develop a uniform European system, recognised as unlikely to be possible from the outset. Rather it was felt to be desirable that it should be possible to translate a site description made under one system to at least an approximate description under another for purposes of Europe-wide planning and research.

The task has proved to be more challenging than was initially anticipated. Substantial progress has been made towards a common view of climate and soil moisture regimes, despite considerable differences between the conditions pertaining in the various countries. In the case of soil nutrient regime, major differences in techniques of soil chemical analysis have been highlighted, which have tended to outweigh the fact that conditions are, in reality, comparable across the relevant area. In particular, the methods of determination of soil nitrogen used in Continental Europe still rely on measures of total nitrogen, as opposed to mineral measures.

Efforts will continue towards achieving the original objectives of this process. In the long term, the advantages of the approaches taken during the development of the Ecological Site Classification will be recognised and adopted more widely on the Continent, as well as in Great Britain.

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Post script:-

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APPENDIX 1
SITE DESCRIPTIONS

SITE AND SOIL PROFILE DESCRIPTION **ABF1**

TOPOGRAPHICAL DETAILS

ELEVATION <10m **ASPECT** W **INCLINE** 1DEG

POSITION SAND FLAT **SHAPE** REGULAR

SOIL TYPE LITTORAL SAND **CODE** 15

HUMUS FORM MORMODER **ROOTING DEPTH** >80cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	4cm	PINE LITTER, LOOSE
O [Fm]	4cm	7cm	COARSE MATERIAL, DARK BROWN
O [Hr]	7cm	7cm	TRACE ONLY, REDDISH BLACK
Ah	7cm	16cm	10YR4/2 DARK GREYISH BROWN [ABUNDANT BLEACHED GRAINS] HUMOSE FINE SAND, STRUCTURELESS, VERY FRIABLE STONELESS, STRONGLY ROOTED
Bg	16cm	41cm	10YR6/8 BROWNISH YELLOW: 10YR7/3 PALE BROWN 70:30 MOTTLE FINE SAND, STRUCTURELESS, VERY FRIABLE STONELESS, WELL ROOTED
Cg	41cm	>81cm	10YR7/2 LIGHT GREY: 10YR5/8 YELLOWISH BROWN 70:30 MOTTLE FINE SAND, STRUCTURELESS, VERY FRIABLE STONELESS, WELL ROOTED

SITE AND SOIL PROFILE DESCRIPTION

ABF2

TOPOGRAPHICAL DETAILS

ELEVATION 120m **ASPECT** N **INCLINE** 22DEG

POSITION MIDSLOPE **SHAPE** REGULAR

SOIL TYPE TYPICAL IRONPAN **CODE** 4

HUMUS FORM HUMIMOR **ROOTING DEPTH**

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	1cm	GRASS AND MOSS LITTER
O [Fm]	1cm	6cm	MATTED LARCH AND GRASS DEBRIS, DARK REDDISH BROWN
O [Hh]	6cm	7cm	GREASY HUMUS, BLACK, FINE
Ah	7cm	11cm	10YR2/2 VERY DARK BROWN / 10YR2/1 BLACK SANDY SILT LOAM, COARSE BLOCKY, FIRM SLIGHTLY STONY, WELL ROOTED
Eg	11cm	24cm	7.5YR7/2 PINKISH GREY / 10YR6/2 LIGHT BROWNISH GREY SANDY SILT LOAM, COARSE SAB, FIRM SLIGHTLY STONY, WEAKLY ROOTED, HUMOSE STAINING
Bf	24cm	24cm	1-2mm DARK RUSTY IRONPAN, VERY INTERMITTENT
Bs	24cm	36cm	7.5YR4/4 DARK BROWN [PALER & YELLOWER BELOW] SANDY SILT LOAM/ SILTY LOAM, FINE SAB, FRIABLE MODERATELY STONY, ROOTED
Cx	36cm	TO DEPTH	5GY7/1 LIGHT GREY: 2.5Y6/4 LIGHT YELLOWISH BROWN 60:40 SANDY SILT LOAM/ SANDY LOAM, VERY FIRM & INDURATED VERY STONY, MECHANICALLY UNROOTABLE

SITE AND SOIL PROFILE DESCRIPTION AE1

TOPOGRAPHICAL DETAILS

ELEVATION 150m **ASPECT** N/A **INCLINE** LEVEL

POSITION ALLUVIAL FLAT **SHAPE** REGULAR

SOIL TYPE ALLUVIAL BR. EARTH **CODE** 1v

HUMUS FORM MULLMODER **ROOTING DEPTH** ~50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	0cm	GRASS LITTER, TRACE ONLY
O [Fa]	0cm	2cm	GRASS DEBRIS, DECOMPOSED
Ah	2cm	9cm	5YR2/2 DARK REDDISH BROWN VERY HUMOSE FINE SAND, STRUCTURELESS, VERY FRIABLE SLIGHTLY STONY, WELL ROOTED
B	9cm	31cm	5YR4/4 REDDISH BROWN FINE SAND, STRUCTURELESS, VERY FRIABLE VERY STONY [PEBBLES TO 20cm IN SIZE], WELL ROOTED
BC	31cm	>41cm	5YR4/4 REDDISH BROWN [LIGHT GLEYING AT BASE] FINE SAND, STRUCTURELESS, VERY FRIABLE EXTREMELY STONY, ROOTED

SITE AND SOIL PROFILE DESCRIPTION   AE2

TOPOGRAPHICAL DETAILS

ELEVATION 150m **ASPECT** N/A **INCLINE** LEVEL

POSITION ALLUVIAL FAN **SHAPE** GENTLE VALLEY

SOIL TYPE ALLUVIAL BR. EARTH **CODE** 1v

HUMUS FORM VERMIMULL **ROOTING DEPTH** 30cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	0cm	SPRUCE LITTER, TRACE ONLY
Ah	0cm	12cm	10YR4/4 DARK YELLOWISH BROWN FINE SILTY SAND, CRUMB/ SAB, FRIABLE MODERATELY STONY, STRONGLY ROOTED
BC	12cm	>42cm	7.5YR4/4 BROWN FINE SILTY SAND, CRUMB/ STRUCTURELESS, VERY FRIABLE VERY STONY [SHALE FLAGS TO 25cm], ROOTED TO 30cm

SITE AND SOIL PROFILE DESCRIPTION BAL1

TOPOGRAPHICAL DETAILS

ELEVATION 300m **ASPECT** N/A **INCLINE** LEVEL

POSITION FLUVI-GLACIAL TERRACE **SHAPE** REGULAR

SOIL TYPE ALLUVIAL BR. EARTH **CODE** 1v

HUMUS FORM HEMIMOR **ROOTING DEPTH** ~50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	2cm	PINE, MOSS AND GRASS LITTER, LOOSE
O [Fm]	2cm	6cm	MATTED HUMUS, REDDISH BROWN
O [Hr/z]	6cm	7cm	FINE GRANULAR HUMUS, REDDISH BROWN
Ah	7cm	22cm	10YR4/4 DARK YELLOWISH BROWN LIGHTLY HUMOSE SILTY SAND, WEAK SAB, VERY FRIABLE SLIGHTLY STONY, WELL ROOTED
BC	22cm	47cm [var]	10YR5/8 YELLOWISH BROWN SILTY SAND, WEAK SAB, FRIABLE [COMPACT BY SETTLEMENT] STONELESS, WELL ROOTED
C	47cm	TO DEPTH	FIELD OF FLUVIALLY ROUNDED GRANITIC BOULDERS

SITE AND SOIL PROFILE DESCRIPTION BCH1

TOPOGRAPHICAL DETAILS

ELEVATION 210m **ASPECT** N/A **INCLINE** LEVEL

POSITION ALLUVIAL FLAT **SHAPE** REGULAR

SOIL TYPE ALLUVIAL G-W GLEY **CODE** 5v

HUMUS FORM MULLMODER **ROOTING DEPTH** >50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	1cm	CONIFER AND MOSS LITTER
O [Fa]	1cm	4cm	MATTED HUMUS, DARK BROWN
O [Hh]	4cm	4cm	DARK HUMUS/ MINERAL MIXTURE
Ah	4cm	10cm	10YR3/3 DARK BROWN HUMOSE SANDY LOAM, MODERATE SAB, FIRM SLIGHTLY STONY, WELL ROOTED
A	10cm	33cm	10YR5/2 GREYISH BROWN GRITTY SAND, STRUCTURELESS, VERY FRIABLE VERY STONY, WELL ROOTED
B	33cm	53cm	10YR3/4 DARK YELLOWISH BROWN GRITTY COARSE SAND, STRUCTURELESS, VERY FRIABLE VERY STONY, WELL ROOTED
BCg	53cm	TO DEPTH	10YR6/2 LIGHT BROWNISH GREY: 2.5YR4/6 RED 60:40 MOTTLE SILTY SAND, STRUCTURELESS, VERY FRIABLE VERY STONY, WELL ROOTED, LOCALLY GLEYED

SITE AND SOIL PROFILE DESCRIPTION — BCH2

TOPOGRAPHICAL DETAILS

ELEVATION 120m **ASPECT** SSE **INCLINE** 10DEG

POSITION UPPER MIDSLOPE **SHAPE** MILDLY BICONCAVE

SOIL TYPE TYPICAL BR. EARTH **CODE** 1

HUMUS FORM MORMODER **ROOTING DEPTH** 35cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	2cm	GRASS LITTER, LIGHT BROWN, DRY
O [Fa]	2cm	5cm	WEAKLY MATTED LITTER
O [Hz]	5cm	6cm	DUSTY DRY HUMUS, BLACK
Ah	6cm	8cm	10YR3/4 DARK YELLOWISH BROWN [WITH SOME BLEACHED GRAINS] VERY HUMOSE FINE SAND, STRUCTURELESS, VERY FRIABLE STONELESS, STRONGLY ROOTED [ESP. BY GRASSES]
A	8cm	17cm	10YR4/3 BROWN/ DARK BROWN FINE SAND, MODERATE SAB, FRIABLE VERY STONY, WELL ROOTED
B	17cm	35cm	10YR6/8 BROWNISH YELLOW/ 10YR5/8 YELLOWISH BROWN FINE SAND, STRUCTURELESS, VERY FRIABLE VERY STONY, ROOTED
C	35cm	TO DEPTH	SOLID GRANITE AND/ OR UNDIGGABLE GLACIAL TILL UNROOTABLE

SITE AND SOIL PROFILE DESCRIPTION

CER 1

TOPOGRAPHICAL DETAILS

ELEVATION 330m **ASPECT** SE **INCLINE** 24 DEG

POSITION UPPER SLOPE **SHAPE** REGULAR

SOIL TYPE UPLAND BR. EARTH **CODE** 1u

HUMUS FORM RHIZOMULL **ROOTING DEPTH** 60cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	GRASS DEBRIS AND LARCH NEEDLES
O [F]	3cm	3cm	TRACE ONLY
Ah	3cm	11cm	10YR5/2 GREYISH BROWN SANDY SILT LOAM, MOD. SUBANGULAR BLOCKY, FRIABLE MODERATELY STONY, WELL ROOTED
B	11cm	31cm	10YR7/6 YELLOW SANDY SILT LOAM, STRONG CRUMB, VERY FRIABLE VERY STONY, WELL ROOTED
C	31cm	>61cm	10YR7/6 YELLOW WITH 7.5YR5/8 STRONG BROWN IN PLACES SANDY SILT LOAM, CRUMB, VERY FRIABLE EXTREMELY STONY, SPARSE ROOTING

SITE AND SOIL PROFILE DESCRIPTION

CHT1

TOPOGRAPHICAL DETAILS

ELEVATION 200m **ASPECT** SW **INCLINE** 11DEG

POSITION MIDSLOPE **SHAPE** MILDLY CONVEX

SOIL TYPE ARGILLIC BR. EARTH **CODE** 12t

HUMUS FORM VERMIMULL **ROOTING DEPTH** >70cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	BEECH LITTER, LOOSE
O [Fz]	3cm	3cm	TRACE ONLY
Ah	3cm	11cm	10R2/1 REDDISH BLACK HUMOSE SANDY CLAY LOAM, WEAK SAB, FRIABLE VERY STONY [FLINTS], WELL ROOTED, WORM CASTS
Eb	11cm	29cm	7.5YR6/6 REDDISH YELLOW SANDY CLAY LOAM/ CLAY LOAM, MODERATE SAB, FIRM VERY STONY [FLINTS], WELL ROOTED, Mn NODULES
B1	29cm	54cm	5YR5/8 YELLOWISH RED CLAY, WEAK AB, VERY FIRM VERY STONY [FLINTS], WELL ROOTED, MANY Mn NODULES
B2	54cm	>69cm	5YR5/8 YELLOWISH RED [WITH MUCH WHITE CHALK MATERIAL] CLAY, MODERATE AB, VERY FIRM VERY STONY [FLINTS], WELL ROOTED, MANY Mn NODULES

SITE AND SOIL PROFILE DESCRIPTION **DEN1**

TOPOGRAPHICAL DETAILS

ELEVATION 130m **ASPECT** SE **INCLINE** 20DEG

POSITION LOWER MIDSLOPE **SHAPE** REGULAR

SOIL TYPE TYPICAL BR. EARTH **CODE** 1

HUMUS FORM VERMIMULL **ROOTING DEPTH** >70cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	OAK LITTER, LOOSE
O [Fz]	3cm	4cm	COARSE LIGHT BROWN MATERIAL, LOOSE
Ah	4cm	16cm	7.5YR3/2 DARK BROWN FINE SANDY LOAM, CRUMB TO WEAK SAB, VERY FRIABLE SLIGHTLY STONY, STRONGLY ROOTED
B	16cm	36cm	7.5YR5/4 BROWN FINE SANDY LOAM, MODERATE SAB, VERY FRIABLE SLIGHTLY STONY, STRONGLY ROOTED
C	36cm	>70cm	5YR5/4 REDDISH BROWN FINE SANDY LOAM, CRUMB, VERY FRIABLE VERY STONY [UP TO 40cm IN SIZE], WELL ROOTED

SITE AND SOIL PROFILE DESCRIPTION **DEN2**

TOPOGRAPHICAL DETAILS

ELEVATION 100m **ASPECT** W **INCLINE** 6-20DEG

POSITION UPPER MIDSLOPE **SHAPE** CONVEX

SOIL TYPE TYPICAL BR. EARTH **CODE** 1

HUMUS FORM MULLMODER **ROOTING DEPTH** >55cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
0 [L]	0cm	2cm	BRACKEN AND GRASS LITTER
0 [Fz]	2cm	7cm	FINE, REDDISH BROWN, FRIABLE
0 [Hz]	7cm	7cm	GRANULAR, BLACK, TRACE ONLY
Ah	7cm	13cm	10YR5/3 BROWN [10YR4/2 DARK GREYISH BROWN ABOVE] FINE SANDY LOAM, WEAK SAB, FRIABLE MODERATELY STONY, WELL ROOTED, RHIZOMES/ BULBS
A	13cm	35cm	10YR5/3 BROWN FINE SANDY LOAM, WEAK SAB, VERY FRIABLE MODERATELY STONY, WELL ROOTED, RHIZOMES/ BULBS
B	35cm	>55cm	7.5YR6/6 REDDISH YELLOW FINE SANDY LOAM, WEAK SAB, VERY FRIABLE VERY STONY, WELL ROOTED

SITE AND SOIL PROFILE DESCRIPTION — DEN3

TOPOGRAPHICAL DETAILS

ELEVATION 130m **ASPECT** ESE **INCLINE** 15DEG

POSITION LOWER MIDSLOPE **SHAPE** MILDLY CONCAVE

SOIL TYPE TYPICAL BR. EARTH **CODE** 1

HUMUS FORM VERMIMULL **ROOTING DEPTH** >60cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
0 [L]	0cm	3cm	OAK LITTER, MID-BROWN
0 [Fz]	3cm	3cm	MID-BROWN, TRACE ONLY
Ah	3cm	21cm	5YR3/1 VERY DARK GREY FINE SANDY LOAM, WEAK SAB, FRIABLE SLIGHTLY STONY, STRONGLY ROOTED, BLUEBELL BULBS
B	21cm	44cm	2.5YR4/4 REDDISH BROWN SANDY SILT LOAM, WEAK SAB, FRIABLE MODERATELY STONY, WELL ROOTED
C	44cm	>62cm	10R4/3 WEAK RED SANDY SILT LOAM, WEAK SAB, FRIABLE VERY STONY [TO 30cm IN SIZE], WELL ROOTED

SITE AND SOIL PROFILE DESCRIPTION   DEN4

TOPOGRAPHICAL DETAILS

ELEVATION 130m   **ASPECT** SW   **INCLINE** 10DEG

POSITION MIDSLOPE   **SHAPE** MILDLY CONVEX

SOIL TYPE BROWN S-W GLEY   **CODE** 7b

HUMUS FORM VERMIMULL   **ROOTING DEPTH** >50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
0 [L]	0cm	1cm	SYCAMORE/ LARCH LITTER, SPARSE
Ah	1cm	12cm	10YR5/2 GREYISH BROWN SANDY CLAY LOAM, STRONG FINE SAB, PEDS FIRM MODERATELY STONY, STRONGLY ROOTED, CASTS/ BULBS
B	12cm	32cm	7.5YR6/4 LIGHT BROWN SANDY CLAY LOAM, STRONG SAB, PEDS FIRM MODERATELY STONY, STRONGLY ROOTED
C	32cm	>44cm	2.5YR4/2 WEAK RED [5Y6/2 LIGHT OLIVE GREY PED FACES] CLAY, PRISMATIC, FIRM MODERATELY STONY, WELL ROOTED, OCHREOUS MOTTLES

SITE AND SOIL PROFILE DESCRIPTION — DEN5

TOPOGRAPHICAL DETAILS

ELEVATION 60m **ASPECT** NW **INCLINE** 3DEG

POSITION UPPER SLOPE **SHAPE** MILDLY CONVEX

SOIL TYPE TYPICAL BR. EARTH **CODE** 1

HUMUS FORM VERMIMULL **ROOTING DEPTH** 80cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
0 [L]	0cm	5cm	OAK LITTER, DARK BROWN, VARIABLE
O [Fz]	5cm	5cm	DISCONTINUOUS TRACE ONLY
Ah	5cm	20cm	5YR6/4 LIGHT REDDISH BROWN [5YR6/3 ABOVE] CLAY LOAM, STRONG SAB, PEDS VERY FIRM STONE FREE, STRONGLY ROOTED
B1	20cm	44cm	2.5YR5/4 REDDISH BROWN CLAY LOAM/ CLAY, STRONG SAB, PEDS FIRM STONE FREE, WELL ROOTED
B2	44cm	69cm	2.5YR5/4 REDDISH BROWN [2.5YR5/3 WEAK RED PED FACES] CLAY LOAM/ CLAY, MODERATE SAB/ PRISMATIC, PEDS FIRM STONELESS, WELL ROOTED
C	69cm	>81cm	2.5YR5/3 WEAK RED [5GY7/1 LIGHT GREENISH GREY STREAKS] CLAY LOAM/ CLAY, WEAK AB, PEDS FIRM STONELESS, OCCASIONAL ROOTS ONLY

SITE AND SOIL PROFILE DESCRIPTION — DEN6

TOPOGRAPHICAL DETAILS

ELEVATION 170m **ASPECT** W **INCLINE** 7-10DEG

POSITION UPPER MIDSLOPE **SHAPE** MILDLY CONCAVE

SOIL TYPE TYPICAL BR. EARTH **CODE** 1

HUMUS FORM VERMIMULL **ROOTING DEPTH** > 50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	OAK AND GRASS LITTER
O [Fz]	3cm	3cm	TRACE ONLY, GRASS RHIZOMES
Ah	3cm	11cm	5YR4/2 DARK REDDISH GREY FINE SANDY SILT LOAM, WEAK SAB, FRIABLE/ FIRM, COMPACT SLIGHTLY STONY, STRONGLY ROOTED, RHIZOMES/ BULBS
B	11cm	29cm	5YR6/4 LIGHT REDDISH BROWN SANDY CLAY LOAM, WEAK SAB, FRIABLE SLIGHTLY STONY, WELL ROOTED, BULBS
BC	29cm	>49cm	2.5YR5/4 REDDISH BROWN SANDY CLAY LOAM, MODERATE SAB, FRIABLE VERY STONY, WELL ROOTED

SITE AND SOIL PROFILE DESCRIPTION

DEN7

TOPOGRAPHICAL DETAILS

ELEVATION 190m **ASPECT** W **INCLINE** 12DEG

POSITION MIDSLOPE **SHAPE** CONCAVE

SOIL TYPE PODZOLIC S-W GLEY **CODE** 7z

HUMUS FORM MORMODER **ROOTING DEPTH** ~50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]/ [Fz]	0cm	13cm	LARCH DEBRIS, DARK REDDISH BROWN
Ah1	13cm	29cm	10YR2/2/ 10YR3/1 VERY DARK GREY HUMOSE SANDY LOAM, STRUCTURELESS, FRIABLE EXTREMELY STONY [S/STONE, CHERT], ROOTED
Ah2	29cm	40cm	10YR4/1 DARK GREY HUMOSE SANDY LOAM, STRUCTURELESS, FRIABLE EXTREMELY STONY [S/STONE, CHERT], WEAKLY ROOTED
Eg	40cm	>60cm	10YR6/2 LIGHT BROWNISH GREY FINE SAND, STRUCTURELESS, FRIABLE EXTREMELY STONY, UNROOTED

SITE AND SOIL PROFILE DESCRIPTION

DOW1

TOPOGRAPHICAL DETAILS

ELEVATION 100m **ASPECT** SE **INCLINE** 6DEG

POSITION UPPER SLOPE **SHAPE** MILDLY CONVEX

SOIL TYPE TYPICAL S-W GLEY **CODE** 7

HUMUS FORM MULLMODER **ROOTING DEPTH** 70cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	BRACKEN AND PINE LITTER, MID-BROWN
O [Fz]	3cm	5cm	LOOSE, REDDISH BROWN, FRASS
Ah	5cm	22cm	2.5Y6/4 LIGHT YELLOWISH BROWN [7.5YR7/8 ORANGE MOTTLES] SANDY CLAY, STRONG SAB, FIRM SLIGHTLY STONY [FLINTS], WELL ROOTED
Bg	22cm	39cm	2.5Y7/2 PALE GREY/ 7.5YR6/8 ORANGE 50:50 MOTTLE CLAY, STRONG SAB, VERY FIRM SLIGHTLY STONY, WELL ROOTED, HUMOSE PED COATINGS
C	39cm	>108cm	5Y6/2 LIGHT OLIVE GREY/ 7.5YR7/8 ORANGE 60:40 MOTTLE CLAY, MODERATE PRISMATIC ABOVE, PLASTIC SLIGHTLY STONY ABOVE, FINE ROOTS TO 70cm

SITE AND SOIL PROFILE DESCRIPTION　　**DOW2**

TOPOGRAPHICAL DETAILS

ELEVATION 100m　**ASPECT** NE　**INCLINE** 1DEG

POSITION LOWER SLOPE　**SHAPE** · REGULAR

SOIL TYPE ARGILLIC BR. EARTH　**CODE** 12t

HUMUS FORM VERMIMULL　**ROOTING DEPTH** 50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	OAK LITTER, WORM CASTS EVIDENT
A	3cm	18cm	10YR6/3 & 5/3 PALE BROWN & BROWN SILT LOAM/ SILTY CLAY LOAM, MODERATE SAB, FIRM VERY STONY [FLINTS], SOME OCHREOUS MOTTLING, BULBS
Eb	18cm	34cm	10YR6/4 LIGHT YELLOWISH BROWN SILT LOAM/ SILTY CLAY LOAM, MODERATE SAB, FIRM VERY STONY [FLINTS], WELL ROOTED
BC	34cm	104cm	5YR5/4 REDDISH BROWN [SHINY PED FACES] CLAY, STRONG SAB, FIRM VERY STONY [FLINTS], ROOTED, BLACK Mn CONCRETIONS

SITE AND SOIL PROFILE DESCRIPTION **DOW3**

TOPOGRAPHICAL DETAILS

ELEVATION 55m **ASPECT** N/A **INCLINE** LEVEL

POSITION GRAVEL FLAT **SHAPE** REGULAR

SOIL TYPE PODZOLIC G-W GLEY **CODE** 5z

HUMUS FORM HEMIMOR **ROOTING DEPTH** >70cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	BRACKEN LITTER, MID-BROWN
O [Fm]	3cm	9cm	BRACKEN LITTER, REDDISH BROWN, MATTED WITH FINES
O [Hr]	9cm	12cm	FINE GRANULAR HUMUS, DUSKY RED
Ah	12cm	20cm	10YR2/2 VERY DARK BROWN [ABUNDANT BLEACHED GRAINS] HUMOSE FINE SAND, STRUCTURELESS, FRIABLE SLIGHTLY STONY [FLINTS], WELL ROOTED
Bh	20cm	30cm	10YR2/2 VERY DARK BROWN HUMOSE FINE SAND, STRUCTURELESS, FRIABLE MODERATELY STONY [FLINTS], WELL ROOTED
Eg	30cm	53cm	10YR6/3 PALE BROWN [GREY/ BROWN MOTTLE IN PLACES] LOAMY SAND/ SANDY LOAM, STRUCTURELESS, FRIABLE MODERATELY STONY [FLINTS], WELL ROOTED
Bg	53cm	>73cm	2.5Y7/2 LIGHT GREY/ 7.5YR5/6 STRONG BROWN 50:50 MOTTLE SANDY CLAY LOAM/ SANDY CLAY, STRUCTURELESS, FRIABLE MODERATELY STONY [FLINTS], ROOTED

SITE AND SOIL PROFILE DESCRIPTION DOW4

TOPOGRAPHICAL DETAILS

ELEVATION 120m **ASPECT** N **INCLINE** 8DEG

POSITION LOWER MIDSLOPE **SHAPE** 2 X CONVEX

SOIL TYPE HARDPAN PODZOL **CODE** 3m

HUMUS FORM HEMIMOR **ROOTING DEPTH** >70cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	PINE LITTER, LIGHT BROWN
0 [Fm]	3cm	7cm	PINE LITTER, MID-BROWN, COARSE, WEAKLY MATTED
O [Hr]	7cm	9cm	FINE GRANULAR HUMUS, DARK REDDISH BROWN
Ah	9cm	12cm	5YR3/2 DARK REDDISH BROWN [STRONG HIDDEN BLEACHING] HUMOSE FINE SAND, STRUCTURELESS, VERY FRIABLE SLIGHTLY STONY, ROOTED
Ea1	12cm	30cm	5YR6/2 PINKISH GREY [HUMOSE BURIED TOPSOIL AT BASE] FINE SAND, STRUCTURELESS, VERY FRIABLE SLIGHTLY STONY, ROOTED
Ea2	30cm	70cm	5YR6/3 LIGHT REDDISH BROWN FINE SAND, STRUCTURELESS, VERY FRIABLE SLIGHTLY STONY, ROOTED
Bh	70cm	82cm	5YR2/1 BLACK HUMOSE FINE SAND, STRUCTURELESS, CEMENTED & FIRM
Bs	80cm	TO DEPTH	7.5YR5/6 STRONG BROWN FINE SAND, STRUCTURELESS, LIGHTLY CEMENTED & FIRM

SITE AND SOIL PROFILE DESCRIPTION **DOW5**

TOPOGRAPHICAL DETAILS

ELEVATION 110m **ASPECT** S **INCLINE** 2DEG

POSITION LOWER SLOPE **SHAPE** REGULAR

SOIL TYPE CALCAR. BR. EARTH **CODE** 12b

HUMUS FORM VERMIMULL **ROOTING DEPTH**

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	0cm	TRACE ONLY
Ah	0cm	18cm	10YR5/3 BROWN [7.5YR5/4 BROWN WITHIN PEDS] SILTY CLAY LOAM, STRONG SAB, VERY FIRM VERY STONY [FLINTS TO 10cm], STRONGLY ROOTED, WORMS
Eb	18cm	>45cm	7.5YR5/5 BROWN/ STRONG BROWN SILTY CLAY LOAM, MODERATE SAB, FIRM VERY STONY [FLINTS], STRONGLY ROOTED, FREE CHALK

SITE AND SOIL PROFILE DESCRIPTION   DOW6

TOPOGRAPHICAL DETAILS

ELEVATION 65m   **ASPECT** E   **INCLINE** 1DEG

POSITION UPPER MIDSLOPE   **SHAPE** REGULAR

SOIL TYPE BROWN S-W GLEY   **CODE** 7b

HUMUS FORM VERMIMULL   **ROOTING DEPTH** >50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	2cm	OAK LITTER
O [Fz}	2cm	3cm	OAK LITTER, LIGHT BROWN, DECOMPOSING
Ah	3cm	19cm	10YR4/2 DARK GREYISH BROWN [10YR5/3 BROWN INSIDE PEDS] CLAY LOAM, STRONG SAB, FIRM SLIGHTLY STONY [FLINTS], WELL ROOTED
Bg	19cm	35cm	10YR5/2 GREYISH BROWN [BROWN/ YELLOW MOTTLE WITHIN PEDS] CLAY LOAM, STRONG COARSE SAB, FIRM SLIGHTLY STONY [FLINTS], WELL ROOTED
BCg	35cm	>50cm	2.5Y6/2 LIGHT BROWNISH GREY [7.5YR6/8 RED. BROWN INSIDE PEDS] CLAY, STRONG PRISMATIC, VERY FIRM SLIGHTLY STONY [FLINTS], ROOTED

SITE AND SOIL PROFILE DESCRIPTION **DST1**

TOPOGRAPHICAL DETAILS

ELEVATION 190m **ASPECT** ESE **INCLINE** 2DEG

POSITION UPPER SLOPE **SHAPE** REGULAR

SOIL TYPE ARGILLIC BR. EARTH **CODE** 12t

HUMUS FORM VERMIMULL **ROOTING DEPTH** >60cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	BEECH LITTER
O [Fz]	3cm	4cm	BEECH DEBRIS AND MAST
Ah	4cm	24cm	10YR5/3 BROWN TO 10YR4/4 DARK YELLOWISH BROWN SILTY LOAM/ SILTY CLAY LOAM, MODERATE SAB, FRIABLE SLIGHTLY STONY, WELL ROOTED, WORM CHAANNELS
B1	24cm	49cm	7.5YR5/6 STRONG BROWN CLAY LOAM, MODERATE SAB, FRIABLE MODERATELY STONY, WELL ROOTED, WORM CHANNELS
B2	49cm	>59cm	7.5YR5/8 STRONG BROWN [SLIGHTLY REDDER THAN B1] CLAY LOAM, MODERATE SAB, FIRM MODERATELY/ VERY STONY, ROOTED

SITE AND SOIL PROFILE DESCRIPTION GTN1

TOPOGRAPHICAL DETAILS

ELEVATION 220m **ASPECT** N **INCLINE** 8DEG

POSITION FLUVI-GLACIAL TERRACE **SHAPE** REGULAR

SOIL TYPE TYPICAL BR. EARTH **CODE** 1

HUMUS FORM MULLMODER **ROOTING DEPTH** 70cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	OAK, GRASS AND MOSS LITTER, LIGHT BROWN
O [Fa]	3cm	4cm	MATTED HUMUS, SOUR AND MYCELIAL, PATCHY
Ah	4cm	37cm	5YR4/4 REDDISH BROWN SANDY CLAY LOAM, STRUCTURELESS, VERY FRIABLE VERY STONY [PEBBLES TO 15cm IN SIZE], STRONGLY ROOTED
B1	37cm	70cm	7.5YR6/8 REDDISH YELLOW COARSE GRAVELLY SAND, STRUCTURELESS, NON-COHESIVE SLIGHTLY STONY, ROOTED
B2g	70cm	>95cm	7.5YR6/4 LIGHT BROWN [POSS. WEAKLY GLEYED] FINE GRITTY SAND, STRUCTURELESS, VERY FRIABLE STONELESS, UNROOTED

SITE AND SOIL PROFILE DESCRIPTION

INV1

TOPOGRAPHICAL DETAILS

ELEVATION 110m **ASPECT** NNW **INCLINE** 3DEG

POSITION LOWER SLOPE **SHAPE** REGULAR

SOIL TYPE PODZOLIC IRONPAN **CODE** 4z

HUMUS FORM HEMIMOR **ROOTING DEPTH** ~50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	1cm	MOSS AND MOSS LITTER
O [Fm]	1cm	4cm	MATTED HUMUS, FINELY DECOMPOSED
O [Hz]	4cm	10cm	DUSTY HUMUS, RED
Eag	10cm	28cm	10YR7/2 LIGHT GREY BLEACHED FINE SAND, MODERATELY PLATY, SLIGHTLY FIRM SLIGHTLY STONY, WELL ROOTED
Bsh	28cm	TO DEPTH	2.5YR3/4 DARK REDDISH BROWN [WITH 10% Eag MATERIAL] FINE SAND, STRONGLY PLATY/ AB, SLIGHTLY FIRM VERY STONY [IN PLACES SKELETAL], WEAKLY ROOTED

SITE AND SOIL PROFILE DESCRIPTION **INV2**

TOPOGRAPHICAL DETAILS

ELEVATION 60m **ASPECT** NW **INCLINE** 8DEG

POSITION UPPER MIDSLOPE **SHAPE** MILDLY CONVEX

SOIL TYPE UPLAND BR. EARTH **CODE** 1u

HUMUS FORM MORMODER **ROOTING DEPTH** >60cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	2cm	MAINLY MOSS LITTER, LIGHT BROWN, LOOSE
O [Fa]	2cm	3cm	PARTLY DECOMPOSED HUMUS, LIGHT BROWN, LOOSE
Ah	3cm	15cm	10YR4/3 BROWN FINE SAND, WEAK CRUMB, FRIABLE SLIGHTLY STONY, STRONGLY ROOTED [ESP. BY GRASSES]
AE	15cm	30cm	10YR6/3 PALE BROWN FINE SAND, STRUCTURELESS, VERY FRIABLE VERY STONY [S/STONES TO 30cm IN SIZE], WELL ROOTED
Bs	30cm	>55cm	10YR5/8 YELLOWISH BROWN FINE SAND, STRUCTURELESS, VERY FRIABLE VERY STONY [S/STONES TO 30cm IN SIZE], WELL ROOTED

SITE AND SOIL PROFILE DESCRIPTION　　　KCD1

TOPOGRAPHICAL DETAILS

ELEVATION 210m　**ASPECT** SSW　**INCLINE** 10DEG

POSITION UPPER MIDSLOPE　**SHAPE** REGULAR

SOIL TYPE TYPICAL BR. EARTH　**CODE** 1

HUMUS FORM MORMODER　**ROOTING DEPTH** ~60cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	8cm	MAT OF GRASS ROOTS, LIGHT BROWN
O [Fa]	8cm	14cm	GRASS DEBRIS, LOOSE
O [Hz]	14cm	15cm	FINE HUMUS, BLACK
Ah	15cm	24cm	5YR3/2 DARK REDDISH BROWN [OCCASIONAL BLEACHED GRAINS] SANDY LOAM, WEAK SAB, FRIABLE VERY STONY [PEBBLES], STRONGLY ROOTED
B	24cm	45cm	2.5YR3/6 DARK RED FINE SANDY LOAM, WEAK SAB, FRIABLE MODERATELY STONY, WELL ROOTED
BC	45cm	>55cm	2.5YR3/4 DARK REDDISH BROWN FINE SANDY LOAM, CRUMB, SLIGHTLY FIRM/ COMPACT VERY STONY, WEAKLY ROOTED

SITE AND SOIL PROFILE DESCRIPTION KCD2

TOPOGRAPHICAL DETAILS

ELEVATION 240m **ASPECT** N **INCLINE** 13DEG

POSITION MIDSLOPE **SHAPE** CONTOUR CONVEX

SOIL TYPE INTERGRADE IRONPAN **CODE** 4b

HUMUS FORM HUMIMOR **ROOTING DEPTH** ~50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	5cm	MAT OF GRASS LITTER, LIGHT BROWN
O [Fa/m]	5cm	9cm	GRASS AND LARCH DEBRIS, MID BROWN, WEAKLY MATTED
O [Hh]	9cm	14cm	PEATY HUMUS, BLACK
Ahg	14cm	20cm	10YR3/4 DARK YELLOWISH BROWN SANDY LOAM, MODERATE SAB/ CLODDY, FRIABLE SLIGHTLY STONY, WELL ROOTED
B	20cm	45cm	2.5YR4/8 RED FINE SANDY LOAM, WEAKLY PLATY/ SAB, VERY FRIABLE VERY STONY, WEAKLY ROOTED
BC	45cm	>59cm	2.5YR4/6 RED FINE SANDY LOAM, WEAKLY PLATY/ SAB, VERY FRIABLE VERY STONY, NO VISIBLE ROOTING

SITE AND SOIL PROFILE DESCRIPTION LAK1

TOPOGRAPHICAL DETAILS

ELEVATION 270m **ASPECT** N **INCLINE** 10DEG

POSITION MIDSLOPE **SHAPE** MILDLY CONVEX

SOIL TYPE TYPICAL S-W GLEY **CODE** 7

HUMUS FORM LEPTOMODER **ROOTING DEPTH** 40cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	10cm	LIVE MOSS MATERIAL, LOOSE
O [Fa]	10cm	14cm	COARSE, FIBROUS HUMUS, REDDISH BROWN
O [Hz]	14cm	15cm	CRUMBLY HUMUS, DARK, LOOSE
A	15cm	29cm	10YR5/4 YELLOWISH BROWN SANDY SILT, MODERATE SAB, FRIABLE STONELESS, STRONGLY ROOTED
B	29cm	39cm	10YR5/6 YELLOWISH BROWN SANDY SILT, WEAK SAB/ CRUMB, FRIABLE STONELESS, WELL ROOTED
BCg	39cm	>64cm	2.5Y7/2 LIGHT GREY: 5YR7/8 YELLOWISH RED 70:30 MOTTLE SILTY CLAY, MODERATELY PLATY, RATHER FIRM STONELESS, WEAK ROOTING AT UPPER SURFACE ONLY

SITE AND SOIL PROFILE DESCRIPTION LAK2

TOPOGRAPHICAL DETAILS

ELEVATION 130m **ASPECT** E **INCLINE** 25DEG

POSITION SLOPE FOOT **SHAPE** REGULAR

SOIL TYPE TYPICAL BR. EARTH **CODE** 1

HUMUS FORM MULLMODER **ROOTING DEPTH** >40cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	0cm	GRASS LITTER, TRACE ONLY
O [Fa/z]	0cm	2cm	SOFT, LOOSE HUMUS, DARK BROWN
Ah	2cm	14cm	10YR3/3 DARK BROWN SILTY LOAM, WEAK SAB, FRIABLE VERY STONY, WELL ROOTED
B	14cm	41cm	7.5YR5/6 STRONG BROWN SILTY CLAY LOAM, CRUMB, VERY FRIABLE VERY STONY [SHALE PIECES TO 20cm IN SIZE], ROOTED
C	41cm	TO DEPTH	7.5YR5/6 STRONG BROWN SILTY CLAY LOAM, CRUMB, VERY FRIABLE EXTREMELY STONY, IN PLACES SKELETAL

SITE AND SOIL PROFILE DESCRIPTION LAK3

TOPOGRAPHICAL DETAILS

ELEVATION 200m **ASPECT** SSW **INCLINE** 25DEG

POSITION LOWER MIDSLOPE **SHAPE** ABRUPTLY CONVEX

SOIL TYPE TYPICAL BR. EARTH **CODE** 1

HUMUS FORM MULLMODER **ROOTING DEPTH** >50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	1cm	GRASS LITTER AND ROOTS
O [Fa]	1cm	3cm	ROOT DEBRIS, LOOSE, DRY
Ah	3cm	8cm	10YR2/2 VERY DARK BROWN HUMOSE FINE SILTY SAND, STRUCTURELESS, VERY FRIABLE MODERATELY STONY, STRONGLY ROOTED
B1	8cm	30cm	7.5YR5/6 STRONG BROWN FINE SILTY SAND, STRUCTURELESS, VERY FRIABLE VERY STONY, WELL ROOTED
B2	30cm	>50cm	7.5YR5/6 STRONG BROWN FINE SILTY SAND, STRUCTURELESS, VERY FRIABLE MODERATELY STONY, WELL ROOTED, MOIST

SITE AND SOIL PROFILE DESCRIPTION LCH1

TOPOGRAPHICAL DETAILS

ELEVATION 130m **ASPECT** NW **INCLINE** 20DEG

POSITION MIDSLOPE **SHAPE** CONTOUR CONVEX

SOIL TYPE INTERGRADE IRONPAN **CODE** 4b

HUMUS FORM RESIMOR **ROOTING DEPTH**

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	4cm	MOSS/ GRASS LITTER, BOUND BY GRASS ROOTS
O [Fm]	4cm	8cm	MATTED HUMUS, LIGHT BROWN
O [Hr]	8cm	15m	LOOSE HUMUS, REDDISH BROWN
Ahg	15cm	16cm	DARK GREY [WITH ABUNDANT BLEACHED GRAINS] CLODDY MICROGLEY/ MICROPODZOL, NO PAN DISCERNIBLE
A	16cm	27cm	10YR5/8 YELLOWISH BROWN SANDY LOAM, WEAK SAB, FRIABLE STONELESS, STRONGLY ROOTED
B	27cm	52cm	7.5YR5/6 STRONG BROWN SANDY SILT LOAM, WEAK SAB, FRIABLE STONELESS, ROOTED
BC	52cm	70cm	7.5YR6/8 REDDISH YELLOW [WITH LIGHT BROWNSH GREY MOTTLING] COARSE SAND, STRUCTURELESS, VERY FRIABLE SLIGHTLY STONY, ROOTING NOT APPARENT
C	70cm	>95cm	5YR4/6 YELLOWISH RED AND OTHER COLOURS COARSE GRITTY SAND/ SANDY LOAM MATRIX LARGE WEATHERED GRANITE BOULDERS

SITE AND SOIL PROFILE DESCRIPTION LND1

TOPOGRAPHICAL DETAILS

ELEVATION <10m **ASPECT** ESE **INCLINE** 4DEG

POSITION DUNE SLACK **SHAPE** IRREGULAR

SOIL TYPE LITTORAL SAND **CODE** 15

HUMUS FORM HEMIMOR **ROOTING DEPTH** >50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	PINE LITTER, LIGHT BROWN
O [Fm]	3cm	8cm	MATTED THROUGHOUT, DENSER WITH FINES BELOW
Ah/ Ea/ Bs	8cm	12cm	Ah - 5YR3/2 D.R. BR. ; Ea - 5YR7/1 L. GR., Bs - 7.5YR4/4 BR. FINE SAND, STRUCTURELESS, VERY FRIABLE STONELESS, ROOTED, MICROPODZOL
C1	12cm	32cm	2.5Y7/3 LIGHT GREYISH YELLOW FINE SAND, STRUCTURELESS, VERY FRIABLE STONELESS, ROOTED
C2	32cm	>42cm	10YR7/4 VERY PALE BROWN FINE SAND, STRUCTURELESS, VERY FRIABLE STONELESS, ROOTED

SITE AND SOIL PROFILE DESCRIPTION — LND2

TOPOGRAPHICAL DETAILS

ELEVATION <10m **ASPECT** N/A **INCLINE** LEVEL

POSITION DUNE LAKE PAN **SHAPE** REGULAR

SOIL TYPE LITTORAL SAND **CODE** 15

HUMUS FORM MULLMODER **ROOTING DEPTH** >80cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	2cm	PINE LITTER
O [Fz]	2cm	6cm	LOOSE FINE HUMUS, DARK BROWN
Ah	6cm	13cm	10YR5/2 GREYISH BROWN FINE SAND, STRUCTURELESS, VERY FRIABLE STONELESS, ROOTED, ABUNDANT KLINKER MATERIAL [INTROD.]
C1	13cm	49cm	2.5Y7/4 PALE YELLOW FINE SAND, STRUCTURELESS, VERY FRIABLE STONELESS, ROOTED
IIAh	49cm	67cm	10YR5/2 GREYISH BROWN [FEINT RUSTY MOTTLING] HUMOSE FINE SAND, STRUCTURELESS, VERY FRIABLE STONELESS, ROOTED, POSSIBLY FORMER BENTHIC DEPOSIT
IICg	67cm	>77cm	2.5Y7/4 PALE YELLOW [WITH ABUNDANT BROWN STREAKS] FINE SAND, STRUCTURELESS, VERY FRIABLE STONELESS, ROOTED

SITE AND SOIL PROFILE DESCRIPTION — LOT1

TOPOGRAPHICAL DETAILS

ELEVATION 305m **ASPECT** E **INCLINE** 16DEG

POSITION UPPER SLOPE **SHAPE** MILDLY CONCAVE

SOIL TYPE TYPICAL BR. EARTH **CODE** 1

HUMUS FORM MULLMODER **ROOTING DEPTH** >60cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	1cm	SPRUCE AND MOSS LITTER
O [Fz]	1cm	3cm	GRANULAR HUMUS, DARK BROWN/ BLACK
Ah	3cm	18cm	10YR6/5 YELLOWISH BROWN [GREYISH BROWN PED FACES] HUMOSE SANDY LOAM, STRONG SAB, FRIABLE MODERATELY STONY, STRONGLY ROOTED
B	18cm	38cm	7.5YR5/4 BROWN SANDY LOAM/ SANDY CLAY LOAM, MODERATE SAB, FRIABLE VERY STONY, WEAKLY ROOTED
C	38cm	>68cm	10YR5/3 BROWN SANDY LOAM, INDETERMINATE, FRIABLE EXTREMELY STONY, WEAKLY ROOTED

SITE AND SOIL PROFILE DESCRIPTION LOT2

TOPOGRAPHICAL DETAILS

ELEVATION 320m **ASPECT** W **INCLINE** 24DEG

POSITION MIDSLOPE **SHAPE** REGULAR

SOIL TYPE UPLAND BR. EARTH **CODE** 1u

HUMUS FORM MORMODER **ROOTING DEPTH** >1m

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	2cm	LARCH LITTER AND GRASS MAT
O [Fa]	2cm	7cm	LARCH/ GRASS LITTER, DARK REDDISH BROWN, FINES BELOW
Ah/Eg/Es	7cm	12cm	10YR4/2 DARK GREYISH BROWN [OLIVE GREY PED CENTRES] SANDY LOAM, COARSE BLOCK/ CRUMB, FRIABLE MODERATELY STONY, WELL ROOTED
A/B	12cm	19cm	10YR4/2 DARK GREYISH BROWN/ 10YR5/3 BROWN SANDY LOAM, CRUMB, FRIABLE MODERATELY STONY, WELL ROOTED
B1	19cm	49cm	10YR5/4 YELLOWISH BROWN SANDY CLAY LOAM, CRUMB, VERY FRIABLE EXTREMELY STONY, WELL ROOTED
B2	49cm	>119cm	7.5YR6/8 REDDISH YELLOW SANDY CLAY LOAM, CRUMB, VERY FRIABLE EXTREMELY STONY, WEAKLY ROOTED

SITE AND SOIL PROFILE DESCRIPTION LWT1

TOPOGRAPHICAL DETAILS

ELEVATION 230m **ASPECT** S **INCLINE** 3DEG

POSITION UPPER MIDSLOPE **SHAPE** 2X CONVEX

SOIL TYPE PODZOLIC RANKER **CODE** 13z

HUMUS FORM HEMIMOR **ROOTING DEPTH** 20cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	PINE LITTER AND MOSS
O [Fm]	3cm	11cm	MATTED HUMUS, MID/ DARK BROWN, FINES INCREASE BELOW
Oh/Ah	11cm	15cm	BLACK SANDY LOAM, STRONG SAB, FIRM SLIGHTLY STONY, ROOTED
C	15cm	>25cm	10YR5/1 GREY SKELETAL RHYOLITE WITH SOME FINES WEAKLY ROOTED

SITE AND SOIL PROFILE DESCRIPTION LWT2

TOPOGRAPHICAL DETAILS

ELEVATION 270m **ASPECT** NW **INCLINE** 9DEG

POSITION UPPER SLOPE **SHAPE** REGULAR

SOIL TYPE UPLAND BR. EARTH **CODE** 1u

HUMUS FORM MULLMODER **ROOTING DEPTH** >50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	2cm	SPRUCE AND FERN LITTER, LIGHT BROWN
O [Fz]	2cm	4cm	LOOSE FINE HUMUS, DARK BROWN, GRANULAR BELOW
A	4cm	19cm	10YR4/4 DARK YELLOWISH BROWN [GREY/ I-P COATED PATCHES] SANDY CLAY LOAM, MODERATE SAB/ CLODDY, FRIABLE MODERATELY STONY, WELL ROOTED
AE	19cm	28cm	2.5Y6/4 LIGHT YELLOWISH BROWN [WITH BROWN HUMOSE PATCHES] SANDY CLAY LOAM, MODERATE SAB, FRIABLE MODERATELY STONY, WELL ROOTED
Bs	28cm	50cm	7.5YR6/8 REDDISH YELLOW SANDY CLAY LOAM, STRONG SAB/ CRUMB, VERY FRIABLE VERY STONY, WELL ROOTED
C	50cm	>62cm	10YR6/6 BROWNISH YELLOW SANDY SILT LOAM, INDETERMINATE, VERY FRIABLE FINES EXTREMELY STONY, ASSUMED UNROOTED

SITE AND SOIL PROFILE DESCRIPTION   MCH1

TOPOGRAPHICAL DETAILS

ELEVATION 60m   **ASPECT** NNW   **INCLINE** 7DEG

POSITION MIDSLOPE   **SHAPE** MILDLY CONCAVE

SOIL TYPE TYPICAL BR. EARTH   **CODE** 1

HUMUS FORM VERMIMULL   **ROOTING DEPTH** >50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	OAK LITTER, LOOSE
O [Fz]	3cm	4cm	OAK DEBRIS, WORM CASTS BELOW
Ah	4cm	12cm	7.5YR4/4 BROWN/ DARK BROWN HUMOSE SANDY CLAY LOAM, MODERATE SAB, FRIABLE SLIGHTLY STONY, WELL ROOTED
B1	12cm	37cm	5YR4/4 REDDISH BROWN SANDY CLAY LOAM, MODERATE SAB, FRIABLE MODERATELY STONY, WELL ROOTED
B2	37cm	53cm	7.5YR4/4 BROWN [LOCALLY 7.5YR5/6] CLAY LOAM, WEAKLY PLATY, SLIGHTLY FIRM MODERATELY STONY, WEAK ROOTING
C	53cm	>58cm	7.5YR5/4 BROWN CLAY LOAM, PLATY, FIRM VERY STONY [ALMOST MATRIX], APPARENTLY ROOTABLE

SITE AND SOIL PROFILE DESCRIPTION MCH2

TOPOGRAPHICAL DETAILS

ELEVATION 190m **ASPECT** E **INCLINE** 8DEG

POSITION LOWER SLOPE **SHAPE** CONCAVE

SOIL TYPE CALCAR. S-W GLEY **CODE** 7k

HUMUS FORM VERMIMULL **ROOTING DEPTH** >50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	0cm	PATCHY MOSS COVER, MUCH BARE SOIL/ MOLE HILLS
Ahg	0cm	15cm	5Y4/1 VERY DARK GREY SILTY CLAY LOAM, STRONG SAB, FRIABLE STONELESS, STRONGLY ROOTED
B1g	15cm	33cm	5Y7/2 LIGHT GREY: 10YR6/8 BROWNISH YELLOW 50:50 MOTTLE SILTY CLAY, STRONG FINE AB/ PRISMATIC, FIRM STONELESS, WEAKLY ROOTED, WORM CHANNELS
B2g	33cm	>53cm	5Y6/1 LIGHT GREY PED FACES [WITH BROWN/ YELLOW MOTTLE] SILTY CLAY, STRONG FINE AB/ PRISMATIC, FIRM STONELESS, WEAKLY ROOTED

SITE AND SOIL PROFILE DESCRIPTION **MID1**

TOPOGRAPHICAL DETAILS

ELEVATION 140m **ASPECT** NE **INCLINE** 4DEG

POSITION VALLEY BOTTOM **SHAPE** STRONGLY CONCAVE

SOIL TYPE PODZOLIC G-W GLEY **CODE** 5z

HUMUS FORM HUMIMOR **ROOTING DEPTH** ~85cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	4cm	BRACKEN LITTER, PALE BROWN, LOOSE
O [Fm/a]	4cm	5cm	BARCKEN DEBRIS, DARK REDDISH BROWN, COMMINUTED
O [Hz]	5cm	9cm	GREASY HUMUS, BLACK, BLOCKY CRUMBLING TO GRANULAR
Ah	9cm	19cm	5YR3/1 VERY DARK GREY [WITH ABUNDANT BLEACHED GRAINS] VERY HUMOSE FINE SAND, WEAK SAB, FRIABLE SLIGHTLY STONY [PEBBLES], WELL ROOTED, BRACKEN RHIZOMES
Ea	19cm	59cm	5YR7/1 LIGHT GREY FINE SAND, STRUCTURELESS, VERY FRIABLE VERY STONY [LARGE PEBBLES], ROOTING WEAKER BELOW
Bh	59cm	84cm	5YR4/1 DARK GREY/ 5YR4/1 GREY SLIGHTLY HUMOSE FINE SAND, STRUCTURELESS, VERY FRIABLE VERY STONY, VERY MOIST, WEAKLY ROOTED
Bhsg	84cm	>89cm	5YR6/8 REDDISH YELLOW/ 5YR4/1 PATCHY COLOURATION SANDY LOAM/ SANDY CLAY LOAM, STRUCTURELESS, FIRM VERY STONY, VERY MOIST, APPARENTLY UNROOTED

SITE AND SOIL PROFILE DESCRIPTION MOR1

TOPOGRAPHICAL DETAILS

ELEVATION 60m **ASPECT** SSE **INCLINE** 16DEG

POSITION SLOPE FOOT **SHAPE** CONVEX

SOIL TYPE PODZOLIC BR. EARTH **CODE** 1z

HUMUS FORM MULLMODER **ROOTING DEPTH** >70cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	4cm	MOSS LITTER, VERY LOOSE
O [Fz]	4cm	6cm	DUSTY HUMUS, VERY FRIABLE
O [Hz]	6cm	7cm	DUSTY HUMUS, DARK BROWN
AE	7cm	11cm	10YR5/2 GREYISH BROWN [WITH ABUNDANT BLEACHED GRAINS] FINE SAND, STRUCTURELESS, VERY FRIABLE STONELESS, STRONGLY ROOTED
A	11cm	27cm	10YR6/4 LIGHT YELLOWISH BROWN VERY FINE SAND, STRUCTURELESS, VERY FRIABLE VERY STONY, STRONGLY ROOTED
BC	27cm	>67cm	10YR5/8 YELLOWISH BROWN VERY FINE SAND, STRUCTURELESS, VERY FRIABLE VERY STONY, WELL ROOTED TO BASE, ERRATIC BOULDERS

SITE AND SOIL PROFILE DESCRIPTION MOR2

TOPOGRAPHICAL DETAILS

ELEVATION <10m **ASPECT** N/A **INCLINE** LEVEL

POSITION SAND FLAT **SHAPE** MILDLY UNDULATING

SOIL TYPE LITTORAL SAND **CODE** 15

HUMUS FORM LEPTOMODER **ROOTING DEPTH** ~40cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	4cm	MOSS LITTER, UNCOMPRESSED
O [Fa]	4cm	9cm	PINE DEBRIS, DARK BROWN, WEAKLY MATTED
O [Hz/r]	9cm	12cm	DUSTY FINE HUMUS, DARK REDDISH BROWN
AE	12cm	20cm	5YR7/2 PINKISH GREY [SOMEWHAT BLEACHED/ GLEYED TONE] MEDIUM FINE SAND, STRUCTURELESS, FRIABLE STONELESS, STRONGLY ROOTED
BCg	20cm	>70cm	7.5YR8/4 PINK: 7.5YR7/8 REDDISH YELLOW 80:20 MOTTLE MEDIUM FINE SAND, STRUCTURELESS, VERY FRIABLE STONELESS, ROOTED TO ABOUT 40cm

SITE AND SOIL PROFILE DESCRIPTION MOR3

TOPOGRAPHICAL DETAILS

ELEVATION 240m **ASPECT** NNW **INCLINE** 2DEG

POSITION UPPER MIDSLOPE **SHAPE** REGULAR

SOIL TYPE PODZOLIC IRONPAN **CODE** 4z

HUMUS FORM HEMIMOR **ROOTING DEPTH** ~30cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	2cm	CONIFER LITTER, LOOSE, FRESH
O [Fm]	2cm	8cm	WEAKLY MATTED CONIFER DEBRIS, REDDISH BROWN
Ea	8cm	20cm	5YR6/2 PINKISH GREY [WITH ABUNDANT HUMIC MATERIAL] FINE SAND, STRUCTURELESS, VERY FRIABLE MODERATELY STONY, STRONGLY ROOTED
Bhs	20cm	31cm	2.5YR2/4 DARK REDDISH BROWN [CULTIVATED O/Ea LOCALLY] HUMOSE FINE SAND, STRUCTURELESS, FRIABLE MODERATELY STONY, WELL ROOTED
Cx	31cm	TO DEPTH	5YR4/8 YELLOWISH RED AND 10YR6/6 BROWNISH YELLOW FINE SANDY LOAM, WEAKLY PLATY, FIRM/ INDURATED MODERATELY STONY, ROOTED

SITE AND SOIL PROFILE DESCRIPTION

NEW1

TOPOGRAPHICAL DETAILS

ELEVATION **ASPECT** NNE **INCLINE** 4DEG

POSITION VALLEY BOTTOM **SHAPE** CONCAVE

SOIL TYPE TYPICAL BR. EARTH **CODE** 1

HUMUS FORM RESIMOR **ROOTING DEPTH** >50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	1cm	PINE AND BRACKEN LITTER
O [Fm]	1cm	2cm	MATTED HUMUS, MID-BROWN, COMPACT
O [Hr]	2cm	5cm	GRANULAR HUMUS, REDDISH BROWN, MATTING CRUMBLING
Ah/E	5cm	18cm	10YR7/6 YELLOW [WITH LIGHT GREY AND BROWN PATCHES] FINE SANDY LOAM, STRUCTURELESS, FIRM STONELESS, ROOTED, LOCALLY GLEYED
B	18cm	35cm	10YR7/5 VERY PALE BROWNISH YELLOW [FEINT MOTTLING] FINE SANDY LOAM, WEAK SAB, FRIABLE STONELESS, ROOTED
BC	35cm	>53cm	10YR6/4 LIGHT YELLOWISH BROWN [BROWN/ RED MOTTLING] SANDY CLAY LOAM, WEAK BLOCKY, FRIABLE STONELESS, ROOTED

SITE AND SOIL PROFILE DESCRIPTION **NTH1**

TOPOGRAPHICAL DETAILS

ELEVATION 95m **ASPECT** S **INCLINE** 2DEG

POSITION UPPER MIDSLOPE **SHAPE** REGULAR

SOIL TYPE ARGILLIC BR. EARTH **CODE** 12t

HUMUS FORM VERMIMULL **ROOTING DEPTH** >60cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	2cm	OAK LITTER, LOOSE, DRY
O [F]	2cm	3cm	OAK DEBRIS, DARK REDDISH BROWN, DECOMPOSED
Ah	3cm	17cm	10YR3/4 DARK YELLOWISH BROWN SANDY SILT LOAM, MODERATE SAB, FRIABLE SLIGHTLY STONY [FLINTS], WELL ROOTED, BLUEBELL BULBS
B1	17cm	39cm	7.5YR5/6 STRONG BROWN SANDY CLAY LOAM, MODERATE SAB, FRIABLE SLIGHTLY STONY [FLINTS], WELL ROOTED, WORM CHANNELS
B2	39cm	59cm	7.5YR5/6 STRONG BROWN SANDY CLAY LOAM, MODERATE SAB, RATHER FIRM SLIGHTLY STONY [FLINTS], WEAKLY ROOTED
Cg	59cm	TO DEPTH	10YR6/8 BROWNISH YELLOW: 2.5Y8/4 PALE YELLOW MOTTLE CLAY, MODERATE COARSE SAB, VERY FIRM WEAKLY ROOTED, Mn BLACK NODULES LOCALLY

SITE AND SOIL PROFILE DESCRIPTION — NTH2

TOPOGRAPHICAL DETAILS

ELEVATION 55m **ASPECT** NNE **INCLINE** 3DEG

POSITION MIDSLOPE **SHAPE** MILDLY DOUBLY CONCAVE

SOIL TYPE CALCAR. S-W GLEY **CODE** 7k

HUMUS FORM VERMIMULL **ROOTING DEPTH** ~50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	0cm	TRACE ONLY, MOSS COVER ON BARE SURFACE
Ah	0cm	21cm	10YR3/4 DARK YELLOWISH BROWN VERY HUMOSE CLAY LOAM, STRONG SAB, RATHER FIRM STONELESS, STRONGLY ROOTED, MANY EARTHWORMS
Bg	21cm	>46cm	2.5Y4/4 OLIVE BROWN: 10YR5/8 YELLOWISH BROWN 60:40 MOTTLE CLAY, MODERATE SAB, VERY FIRM VERY STONY [LIMESTONE FLAGS UP TO 30cm IN SIZE], WEAKLY ROOTED

SITE AND SOIL PROFILE DESCRIPTION NYM1

TOPOGRAPHICAL DETAILS

ELEVATION 70m **ASPECT** WSW **INCLINE** 4DEG

POSITION SLOPE FOOT **SHAPE** CONCAVE

SOIL TYPE BROWN G-W GLEY **CODE** 5b

HUMUS FORM LEPTOMODER **ROOTING DEPTH** ~45cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	2cm	LEAVES AND TWIGS, LOOSE, MOSS COVER LOCALLY
O [Fa]	2cm	4cm	MATTED HUMUS, DARK BROWN, FINES INCREASE BELOW
O [Hz]	4cm	5cm	GRANULAR HUMUS, BLACK, LOOSE
Ah	5cm	6cm	BLACK HUMOSE SANDY CLAY LOAM, MODERATE SAB/ CLODDY, FIRM SLIGHTLY STONY, WELL ROOTED
A	6cm	28cm	2.5Y3/2 VERY DARK GREYISH BROWN [WITH 2.5Y7/8 YELLOW] HUMOSE SANDY CLAY LOAM, MODERATE SAB/ CLODDY, FIRM SLIGHTLY STONY, WELL ROOTED
Bg	28cm	>43cm	10YR6/8 BROWNISH YELLOW [WITH GREYISH BROWN FROM ABOVE] SANDY CLAY LOAM/ SANDY CLAY, MODERATE SAB, FIRM VERY STONY [SHELLY LIMESTONE], WEAKLY ROOTED, WORMS

SITE AND SOIL PROFILE DESCRIPTION SEA1

TOPOGRAPHICAL DETAILS

ELEVATION 220m **ASPECT** WSW **INCLINE** 3DEG

POSITION LOWER MIDSLOPE **SHAPE** REGULAR

SOIL TYPE TYPICAL PODZOL **CODE** 3

HUMUS FORM RESIMOR **ROOTING DEPTH** ~50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	1cm	FRESH PINE LITTER AND MOSS
O [Fa/z]	1cm	6cm	FINE CRUMBLY HUMUS, DARK BROWN, WELL DECOMPOSED
O [Hz]	6cm	13cm	DUSTY HUMUS, DARK REDDISH BROWN, LOOSE
Ea	13cm	21cm	10YR6/2 LIGHT BROWNISH GREY STRONGLY BLEACHED MEDIUM SAND, STRUCTURELESS, FRIABLE STONELESS, WELL ROOTED
Bsh	21cm	31cm	7.5YR5/6 STRONG BROWN/ 10YR3/4 DARK YELLOWISH BROWN MEDIUM FINE SAND, STRUCTURELESS, FRIABLE STONELESS, WELL ROOTED, DIFFUSE DEPOSITION OF C/Fe
B	31cm	53cm	7.5YR6/8 REDDISH YELLOW MEDIUM SAND, STRUCTURELESS, VERY FRIABLE STONELESS, ROOTED
C	53cm	TO DEPTH	10YR7/8 YELLOW SKELETAL TILL, INDETERMINATE, COMPACT AND INDURATED EXTREMELY STONY, MECHANICALLY UNROOTABLE

SITE AND SOIL PROFILE DESCRIPTION SEW1

TOPOGRAPHICAL DETAILS

ELEVATION 370m **ASPECT** WSW **INCLINE** 30DEG

POSITION MIDSLOPE **SHAPE** REGULAR

SOIL TYPE UPLAND BR. EARTH **CODE** 1u

HUMUS FORM MORMODER **ROOTING DEPTH** >60cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	PINE LITTER, LIGHT BROWN, LOOSE
O [Fa]	3cm	7cm	PINE AND GRASS LITTER, MID-BROWN, LOOSE
Ah	7cm	11cm	10YR2/1 BLACK AND 10YR4/1DARK GREY HUMOSE SANDY CLAY LOAM, WEAK SAB, FRIABLE MODERATELY STONY, WELL ROOTED, BRACKEN RHIZOMES
AE	11cm	31cm	10YR6/5 YELLOWISH BROWN [10YR5/3 BROWN ABOVE] SANDY CLAY LOAM, MODERATE SAB, VERY FRIABLE MODERATELY STONY, WELL ROOTED
Bs	31cm	49cm	5YR6/8 REDDISH YELLOW SANDY CLAY LOAM, CRUMB, VERY FRIABLE VERY STONY, WELL ROOTED, BRACKEN RHIZOMES
BC	49cm	61cm	7.5YR5/6 STRONG BROWN SANDY CLAY LOAM, CRUMB, VERY FRIABLE EXTREMELY STONY [UP TO 30cm IN SIZE], ROOTED

SITE AND SOIL PROFILE DESCRIPTION — SFD1

TOPOGRAPHICAL DETAILS

ELEVATION 65m **ASPECT** NE **INCLINE** 1DEG

POSITION RIDGE TOP **SHAPE** CONVEX

SOIL TYPE BROWN S-W GLEY **CODE** 7b

HUMUS FORM MULLMODER **ROOTING DEPTH** ~50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	2cm	PINE LITTER, LOOSE
O [Fz]	2cm	5cm	FINE GRANULAR HUMUS, BLACK, DECOMP. LITTER MATRIX
Ah	5cm	9cm	5YR2/2 DARK REDDISH BROWN [WITH OCC. BLEACHED GRAINS] VERY HUMOSE SANDY LOAM, STRUCTURELESS, VERY FRIABLE STONELESS, WELL ROOTED
A	9cm	24cm	10YR4/4 DARK YELLOWISH BROWN [WITH LIGHTER PATCHES] SANDY CLAY LOAM, MODERATE SAB, FRIABLE MODERATELY STONY, WELL ROOTED
Bg	24cm	46cm	10YR6/6 BROWNISH YELLOW: 10YR6/1 LIGHT GREY 50:50 MOTTLE SANDY CLAY LOAM, MODERATELY PLATY, FIRM VERY STONY [S'STONES UP TO 15cm IN SIZE], WEAKLY ROOTED, Mn NODU
BCg	46cm	>51cm	10YR5/2 GREYISH BROWN [WITH YELLOW AND GREY MOTTLING] SANDY CLAY, PLATY, FIRM VERY STONY, WEAKLY ROOTED

SITE AND SOIL PROFILE DESCRIPTION — SNT 1

TOPOGRAPHICAL DETAILS

ELEVATION 30m **ASPECT** SSE **INCLINE** 10DEG

POSITION UPPER MIDSLOPE **SHAPE** UNDULATING

SOIL TYPE TYPICAL PEATY GLEY **CODE** 6

HUMUS FORM HUMIMOR **ROOTING DEPTH** >80cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
0 [L]	0cm	1cm	OAK LITTER
O [Fa]	1cm	2cm	OAK DEBRIS, DECOMPOSED
O [Hh]	2cm	14cm	PEATY HUMUS, FULLY HUMIFIED
A	14cm	41cm	10YR6/3 PALE BROWN FINE GRITTY SAND, WEAKLY PLATY, FRIABLE SLIGHTLY STONY, WELL ROOTED
BC	41cm	>76cm	10YR6/8 BROWNISH YELLOW: 10YR5/1 GREY 50:50 MOTTLE GRITTY SILTY SAND, STRUCTURELESS, FRIABLE MODERATELY STONY, ROOTED TO BASE

SITE AND SOIL PROFILE DESCRIPTION SWD1

TOPOGRAPHICAL DETAILS

ELEVATION 110m **ASPECT** NE **INCLINE** 7DEG

POSITION UPPER MIDSLOPE **SHAPE** CONVEX

SOIL TYPE ARGILLIC BR. EARTH **CODE** 12t

HUMUS FORM VERMIMULL **ROOTING DEPTH** >60cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	0cm	TRACE ONLY, MOSS COVER ON MINERAL SURFACE
Ah	0cm	20cm	10YR4/2 DARK GREYISH BROWN/ 10YR6/4 LIGHT YELLOWISH BROWN SILTY CLAY LOAM, STRONG SAB [ESP. ABOVE], FRIABLE STONELESS, WELL ROOTED, MANY WORM CHANNELS
Eb	20cm	40cm	7.5YR5/4 BROWN SILTY CLAY LOAM/ CLAY LOAM, MODERATE SAB, FRIABLE/ FIRM STONELESS, WELL ROOTED, WORM CHANNELS
Bt	40cm	50cm	5YR4/4 REDDISH BROWN CLAY LOAM, MODERATE SAB/ PRISMATIC, FIRM STONELESS, WELL ROOTED, WORM CHANNELS
C	50cm	>60cm	5YR4/4 REDDISH BROWN CLAY LOAM, MODERATE SAB/ PRISMATIC, FIRM EXTREMELY STONY [YELLOW L'STONE], ROOTED

SITE AND SOIL PROFILE DESCRIPTION — SWD2

TOPOGRAPHICAL DETAILS

ELEVATION 100m **ASPECT** NNW **INCLINE** 5DEG

POSITION MIDSLOPE **SHAPE** MILDLY CONVEX

SOIL TYPE TYPICAL BR. EARTH **CODE** 1

HUMUS FORM RESIMOR **ROOTING DEPTH** >70cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	PINE LITTER, LOOSE, DRY
O [F]	3cm	6cm	MATTED HUMUS, REDDISH BROWN, INCREASING FINES BELOW
O [Hz]	6cm	8cm	GRANULAR HUMUS, DARK REDDISH BROWN, LOOSE
Ah	8cm	10cm	10R2/2 VERY DUSKY RED [WITH 40% BLEACHED GRAINS] VERY HUMOSE FINE SAND, STRUCTURELESS, VERY FRIABLE STONELESS, WELL ROOTED
A	10cm	25cm	5YR4/2 DARK REDDISH GREY [WITH SOME BLEACHED GRAINS] SLIGHTLY HUMOSE FINE SAND, STRUCTURELESS, FRIABLE MODERATELY STONY [PEBBLES], WELL ROOTED
Bs	25cm	35cm	5YR5/6 / 5YR5/8 YELLOWISH RED FINE SAND, STRUCTURELESS, FRIABLE SLIGHTLY STONY [PEBBLES], WELL ROOTED, DISCONTINUOUS
C	35cm	>70cm	5YR4/8 YELLOWISH RED FINE SAND, STRUCTURELESS, FRIABLE SLIGHTLY STONY [PEBBLES], WEAKLY ROOTED

SITE AND SOIL PROFILE DESCRIPTION SWD3

TOPOGRAPHICAL DETAILS

ELEVATION 85m **ASPECT** NE **INCLINE** 1DEG

POSITION SAND FLAT **SHAPE** REGULAR

SOIL TYPE PODZOLIC BR. EARTH **CODE** 1z

HUMUS FORM HEMIMOR **ROOTING DEPTH**

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	1cm	LARCH LITTER, LOOSE
O [Fm]	1cm	6cm	MATTED LARCH DEBRIS, REDDISH BROWN, FINER BELOW
O [Hz/r]	6cm	7cm	FINE GRANULAR HUMUS, DARK REDDISH BROWN
Ah	7cm	7cm	TRACE ONLY
AE	7cm	14cm	10YR3/1 VERY DARK GREY [WITH 20% BLEACHED GRAINS] HUMOSE FINE SAND, STRUCTURELESS, VERY FRIABLE STONELESS, WELL ROOTED
E/B	14cm	25cm	7.5YR5/6 STRONG BROWN [FREQUENT BLEACHED GRAINS] FINE SAND, STRUCTURELESS, VERY FRIABLE SLIGHTLY STONY, WELL ROOTED
B	25cm	55cm	7.5YR5/6 STRONG BROWN FINE SAND, STRUCTURELESS, FRIABLE SLIGHTLY STONY, WELL ROOTED
BC	55cm	>65cm	7.5YR5/6 STRONG BROWN FINE SAND, STRUCTURELESS, FRIABLE SLIGHTLY STONY, ROOTED

SITE AND SOIL PROFILE DESCRIPTION **SWP1**

TOPOGRAPHICAL DETAILS

ELEVATION 60m **ASPECT** ESE **INCLINE** 20DEG

POSITION LOWER SLOPE **SHAPE** CONCAVE

SOIL TYPE TYPICAL BR. EARTH **CODE** 1

HUMUS FORM LEPTOMODER **ROOTING DEPTH** ~90cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	2cm	SPRUCE LITTER
O [Fm]	2cm	4cm	MATTED SPRUCE DEBRIS, PALE BROWN
O [Hr]	4cm	7cm	DUSTY HUMUS, DARK REDDISH BROWN, FRIABLE
Ah	7cm	9cm	10YR4/2 GREYISH BROWN HUMOSE LOAM, SLIGHTLY STONY, STRONGLY ROOTED
A	9cm	36cm	5YR4/4 REDDISH BROWN SANDY SILT LOAM, STRONG SAB/ CRUMB, FRIABLE SLIGHTLY STONY, STRONGLY ROOTED
B	36cm	61cm	5YR4/4 REDDISH BROWN SANDY SILT LOAM, STRONG SAB, FRIABLE MODERATELY STONY, STRONGLY ROOTED
BC	61cm	91cm	7.5YR5/6 STRONG BROWN SILT LOAM, MODERATE SAB, SLIGHTLY FIRM MODERATELY STONY, WEAKLY ROOTED
C	91cm	>101cm	2.5Y6/2 LIGHT BROWNISH GREY SILT LOAM, PLATY, FIRM VERY STONY, APPARENTLY UNROOTED

SITE AND SOIL PROFILE DESCRIPTION SWP2

TOPOGRAPHICAL DETAILS

ELEVATION 190m **ASPECT** W **INCLINE** 4DEG

POSITION UPPER SLOPE **SHAPE** MILDLY CONVEX

SOIL TYPE INTERGRADE IRONPAN **CODE** 4b

HUMUS FORM MORMODER **ROOTING DEPTH** ~60cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	1cm	LARCH LITTER AND MOSS
O [Fa]	1cm	4cm	MATTED HUMUS, DARK REDDISSH BROWN
Ah/ Eg	4cm	11cm	1OYR6/2 LIGHT BROWNISH GREY / 10YR3/1 VERY DARK GREY SILT LOAM, MODERATE COARSE SAB, SLIGHTLY FIRM BLOCKS MODERATELY STONY, ROOTED
B1	11cm	23cm	10YR6/4 & 10YR6/6 LIGHT YELLOWISH BROWN SILTY CLAY LOAM, MODERATE SAB, FRIABLE MODERATELY STONY, ROOTED
B2s	23cm	45cm	7.5YR5/8 STRONG BROWN SILTY CLAY LOAM/ CLAY LOAM, STRONG SAB, FRIABLE SLIGHTLY STONY, ROOTED
C	45cm	>57cm	10YR 7/6 YELLOW / 10YR6/6 BROWNISH YELLOW SILTY CLAY, WEAKLY PLATY, FRIABLE MODERATELY STONY, WEAKLY ROOTED

SITE AND SOIL PROFILE DESCRIPTION SWP3

TOPOGRAPHICAL DETAILS

ELEVATION 230m **ASPECT** E **INCLINE** 24DEG

POSITION MIDSLOPE **SHAPE** REGULAR

SOIL TYPE TYPICAL BR. EARTH **CODE** 1

HUMUS FORM MORMODER **ROOTING DEPTH** ~60cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	2cm	LARCH AND FERN LITTER, LOOSE
O [Fa]	2cm	5cm	WEAKLY MATTED HUMUS, DARK BROWN, FRIABLE, FRAGMENTED
Ah	5cm	7cm	2.5YR2/0 BLACK VERY HUMOSE FINE SAND, WEAK SAB, FRIABLE SLIGHTLY STONY
A	7cm	27cm	5YR3/4 DARK REDDISH BROWN SLIGHTLY HUMOSE FINE SANDY LOAM, WEAK SAB, FRIABLE MODERATELY STONY, WELL ROOTED
B	27cm	49cm	2.5YR4/4 REDDISH BROWN FINE SANDY LOAM, MODERATE SAB, SLIGHTLY FIRM VERY STONY, WEAKLY ROOTED
C	49cm	>59cm	10R4/6 RED FINE SANDY LOAM, STRUCTURELESS, FRIABLE VERY STONY, WEAKLY ROOTED

SITE AND SOIL PROFILE DESCRIPTION — TAY1

TOPOGRAPHICAL DETAILS

ELEVATION 320m **ASPECT** SSW **INCLINE** 16DEG

POSITION MIDSLOPE **SHAPE** MILDLY CONCAVE

SOIL TYPE UPLAND BR. EARTH **CODE** 1u

HUMUS FORM RHIZOMULL **ROOTING DEPTH** >50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	GRASS LITTER, TIGHTLY WOVEN WITH MOSSES
O [F]	3cm	4cm	GRANULAR HUMUS, DRY, INDISTINCT
Ah	4cm	20cm	10YR4/4 DARK YELLOWISH BROWN FINE SANDY LOAM, STRUCTURELESS, VERY FRIABLE MODERATELY STONY, INTENSE GRASS ROOTING
B	20cm	50cm	7.5YR5/6 STRONG BROWN SANDY SILT LOAM, STRUCTURELESS, VERY FRIABLE MODERATELY STONY, STRONGLY ROOTED
C	50cm	TO DEPTH	7.5YR5/6 STRONG BROWN SANDY SILT LOAM, STRUCTURELESS, VERY FRIABLE EXTREMELY STONY/ SKELETAL

SITE AND SOIL PROFILE DESCRIPTION — TAY2

TOPOGRAPHICAL DETAILS

ELEVATION 20m **ASPECT** S **INCLINE** LEVEL

POSITION SLOPE FOOT **SHAPE** MILDLY DOUBLY CONCAVE

SOIL TYPE BASIC BR. EARTH **CODE** 1d

HUMUS FORM VERMIMULL **ROOTING DEPTH** 50cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	0cm	SPARSE BEECH LEAVES LOCALLY, MOSTLY BARE MINERAL
Ah	0cm	15cm	10YR2/2 VERY DARK BROWN HUMOSE SANDY SILT LOAM, WEAK SAB, FRIABLE SLIGHTLY STONY, STRONGLY ROOTED
B	15cm	50cm	10YR4/3 BROWN/ DARK BROWN SANDY CLAY LOAM, WEAKLY PLATY, VERY FIRM AND COMPACT VERY STONY, ROOTING WEAKER BELOW
Cxg	50cm	TO DEPTH	2.5Y5/2 GREYISH BROWN [WITH 7.5YR5/6 STRONG BROWN] HEAVY CLAY TILL, PLATY, COMPACT AND INDURATED STONELESS, MECHANICALLY UNROOTABLE

SITE AND SOIL PROFILE DESCRIPTION THT1

TOPOGRAPHICAL DETAILS

ELEVATION 50m **ASPECT** N/A **INCLINE** LEVEL

POSITION FLAT **SHAPE** REGULAR

SOIL TYPE ARGILLIC BR. EARTH **CODE** 12t

HUMUS FORM MULLMODER **ROOTING DEPTH** 70cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L, Fa]	0cm	2cm	MAINLY F HUMUS, EVIDENCE OF WORM ACTIVITY
Ah	2cm	11cm	7.5YR3/2 DARK BROWN AND 7.5YR6/2 PINKISH GREY HUMOSE FINE SAND, STRUCTURELESS, FRIABLE SLIGHTLY STONY [FLINTS], WELL ROOTED
A	11cm	36cm	7.5YR5/4 BROWN SLIGHTLY HUMOSE FINE SAND, STRUCTURELESS, FRAIBLE SLIGHTLY STONY [FLINTS], WELL ROOTED
Eb	36cm	62cm	7.5YR5/6 STRONG BROWN FINE SAND, STRUCTURELESS, FRIABLE SLIGHTLY STONY [FLINTS], WELL ROOTED
Bt	62cm	70cm	5YR5/8 / 5YR4/8 YELLOWISH RED SANDY LOAM, STRUCTURELESS, SLIGHTLY FIRM SLIGHTLY STONY [FLINTS], ROOTED
C	70cm	TO DEPTH	10YR7/4 VERY PALE BROWN FINE SAND/ CARBONATE, INDETERMINATE, VERY FIRM SLIGHTLY STONY [FLINTS], WEAKLY ROOTED

SITE AND SOIL PROFILE DESCRIPTION — THT2

TOPOGRAPHICAL DETAILS

ELEVATION <10m **ASPECT** N/A **INCLINE** LEVEL

POSITION FLAT **SHAPE** REGULAR

SOIL TYPE HARDPAN PODZOL **CODE** 3m

HUMUS FORM HEMIMOR **ROOTING DEPTH** 40cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	PINE LITTER, LIGHT BROWN
O [Fm]	3cm	8cm	WEAKLY MATTED HUMUS, BROWN
O [Hz]	8cm	10cm	GRANULAR HUMUS, DARK BROWN, COMPACT
Ea	10cm	40cm	10YR5/1 GREY / 10YR6/2 BROWNISH GREY [BLEACHED] FINE SAND, WEAKLY PLATY, FRIABLE SLIGHTLY STONY [FLINTS], WELL ROOTED
Bhs	40cm	50cm	10YR2/2 VERY DARK BROWN FINE SAND, STRONGLY PLATY, CEMENTED AND VERY FIRM MODERATELY STONY [FLINTS], ROOTING IMPEDED
C	90cm	>160cm	10YR6/4 PALE BROWN [WITH MANY DARK HUMIC STREAKS] SAND, STRUCTURELESS, FRIABLE MODERATELY STONY [FLINTS], ROOTING VERY SPARSE

SITE AND SOIL PROFILE DESCRIPTION THT3

TOPOGRAPHICAL DETAILS

ELEVATION 30m **ASPECT** SW **INCLINE** 2DEG

POSITION LOWER SLOPE **SHAPE** MILDLY CONCAVE

SOIL TYPE CALCAR. BR. EARTH **CODE** 12b

HUMUS FORM VERMIMULL **ROOTING DEPTH** >55cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	0cm	ENTIRELY ABSENT
Ah	0cm	28cm	10YR4/3 DARK BROWN CLAY LOAM, MODERATE SAB, FIRM SLIGHTLY CHALKY, STRONGLY ROOTED, WORM CHANNELS
B	28cm	45cm	10YR5/6 YELLOWISH BROWN SANDY CLAY LOAM, MODERATE SAB, FIRM CHALKY, STRONGLY ROOTED, WORM CCHANNELS
C	45cm	>55cm	10YR5/4 YELLOWISH BROWN SANDY CLAY LOAM MATRIX PREDOMINANTLY CHALK, WELL ROOTED

SITE AND SOIL PROFILE DESCRIPTION THT4

TOPOGRAPHICAL DETAILS

ELEVATION <10m **ASPECT** N/A **INCLINE** LEVEL

POSITION FLAT **SHAPE** REGULAR

SOIL TYPE ARGILLIC BR. EARTH **CODE** 12t

HUMUS FORM LEPTOMODER **ROOTING DEPTH** >90cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [Fz]	0cm	6cm	GRANULAR HUMUS, DARK BROWN
AE	6cm	11cm	10YR6/3 PALE BROWN [WITH MANY BLEACHED GRAINS] FINE SAND, STRUCTURELESS, VERY FRIABLE SLIGHTLY STONY, WELL ROOTED
A	11cm	28cm	10YR6/3 PALE BROWN FINE SAND, STRUCTURELESS, VERY FRIABLE SLIGHTLY STONY, WELL ROOTED
Eb	28cm	80cm	10YR6/6 BROWNISH YELLOW SAND, STRUCTURELESS, VERY FRIABLE MODERATELY STONY, WELL ROOTED
Bt	80cm	>90cm	5YR4/8 YELLOWISH RED SANDY LOAM/ SANDY CLAY LOAM, STRUCTURELESS, FIRM SLIGHTLY STONY, ROOTED, BLACK Mn PARTICLES

SITE AND SOIL PROFILE DESCRIPTION THT5

TOPOGRAPHICAL DETAILS

ELEVATION 30m **ASPECT** N/A **INCLINE** LEVEL

POSITION FLAT **SHAPE** REGULAR

SOIL TYPE ARGILLIC BR. EARTH **CODE** 12t

HUMUS FORM RESIMOR **ROOTING DEPTH** >90cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	2cm	PINE AND CHESTNUT LITTER
O [Fm]	2cm	5cm	WEAKLY MATTED/ GRANULAR HUMUS/ DARK REDDISH BROWN
O [Hr]	5cm	8cm	GRANULAR HUMUS, DARK REDDISH BROWN
A	8cm	27cm	10YR6/4 LIGHT YELLOWISH BROWN FINE SAND, STRUCTURELESS, VERY FRIABLE SLIGHTLY STONY, WELL ROOTED
Eb	27cm	95cm	10YR6/6 BROWNISH YELLOW FINE SAND, STRUCTURELESS, VERY FRIABLE SLIGHTLY STONY, WELL ROOTED
Bt	95cm	105cm	5YR5/8 YELLOWISH RED SANDY LOAM, STRUCTURELESS, FRIABLE MODERATELY STONY, WELL ROOTED
C	105cm	TO DEPTH	2.5Y8/4 PALE YELLOW SANDY LOAM, PLATY, FIRM VERY STONY, ROOTED

SITE AND SOIL PROFILE DESCRIPTION THT6

TOPOGRAPHICAL DETAILS

ELEVATION 50m **ASPECT** N/A **INCLINE** LEVEL

POSITION FLAT **SHAPE** REGULAR

SOIL TYPE PODZOLIC BR. EARTH **CODE** 1z

HUMUS FORM MORMODER **ROOTING DEPTH** >90cm

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	OAK AND BRACKEN LITTER
O [Fa]	3cm	6cm	COARSE GRANULAR HUMUS, DARK REDDISH BROWN
Oh/ Ah	6cm	9cm	EXTREMELY HUMOSE SAND, DARK REDDISH BROWN
AhE	9cm	29cm	10YR5/2 GREYISH BROWN [DARKER ABOVE] FINE SAND, STRUCTURELESS, VERY FRIABLE SLIGHTLY STONY [FLINTS], ROOTED
Bhs	29cm	48cm	5YR4/4 REDDISH BROWN FINE SAND, STRUCTURELESS, VERY FRIABLE SLIGHTLY STONY [FLINTS], ROOTED
Bs	48cm	65cm	7.5YR4/4 BROWN/ DARK BROWN FINE SAND, STRUCTURELESS, VERY FRIABLE SLIGHTLY STONY [FLINTS], ROOTED
BC	65cm	TO DEPTH	7.5YR5/6 STRONG BROWN FINE SAND, STRUCTURELESS, VERY FRIABLE SLIGHTLY STONY [FLINTS], WEAKLY ROOTED

SITE AND SOIL PROFILE DESCRIPTION　　WLD1

TOPOGRAPHICAL DETAILS

ELEVATION 90m　**ASPECT** NNE　**INCLINE** 1DEG

POSITION UPPER SLOPE　**SHAPE** REGULAR

SOIL TYPE PODZOLIC S-W GLEY　**CODE** 7z

HUMUS FORM HEMIMOR　**ROOTING DEPTH**

PROFILE DESCRIPTION

LAYER	TOP DEPTH	BASE DEPTH	DESCRIPTION
O [L]	0cm	3cm	PINE AND MOSS LITTER
O [Fm]	3cm	6cm	MATTED HUMUS, MID/ DARK BROWN
O [Hr]	6cm	7cm	GRANULAR HUMUS, DARK REDDISH BROWN
O [Hh]	7cm	8cm	GREASY HUMUS, BLACK
Ah	8cm	22cm	10YR4/1 DARK GREY AND 10YR5/1 GREY FINE SANDY LOAM/ LOAMY SAND, STRUCTURELESS, FRIABLE SLIGHTLY STONY, WELL ROOTED, BURIED HUMUS BELOW
Ea	22cm	30cm	10YR8/1 WHITE AND 10YR6/2 LIGHT BROWNISH GREY VERY FINE SAND, PLATY, FIRM SLIGHTLY STONY, ROOTED
Bhg	30cm	42cm	10YR7/2 LIGHT GREY [DARK GREYISH BROWN STREAKS] VERY FINE LOAMY SAND, PLATY, FIRM VERY STONY, ROOTED
Bg	42cm	>58cm	10YR7/6 YELLOW : 10YR7/1LIGHT GREY 75:25 PATCHY VERY FINE LOAMY SAND, STRUCTURELESS, FRIABLE/ FIRM VERY STONY, WEAKLY ROOTED

APPENDIX 2
SOIL PHYSICAL DATA

KEY TO SOIL PHYSICAL DATA TABLES

SUM L	= total core length collected for a given layer
SUM L(a)	= adjusted total base layer core length [=SUM L for top and middle]
n	= number of cores taken
MEAN L(a)	= mean layer thickness for site [SUM L(a)/ n]
d	= effective internal diameter of corer(s) used on site
M[BTF]	= field-moist mass of bulk soil sample collected
M[LTF]	= field-moist mass of laboratory soil sample collected
M [TF]	= field-moist mass of total soil sample collected [M[BTF] + M[LTF]]
M [ATF]	= field-moist mass of soil sample to be air-dried
M [ASA]	= air-dry mass of stones arising from M [ATF]
M [LFO]	= oven-dry mass of fine-earth arising from M [LTF]
M [LSO]	= oven-dry mass of stones arising from M [LTF]
S	= dry stone mass fraction of field-moist total soil sample
M [FF]	= field-moist mass of fine-earth arising from M [TF]
M [FO]	= oven-dry mass of fine-earth arising from M [TF]
RATIO	= M [FO] / M [FF]
D [FO]	= mass of oven-dry fine-earth per m^3 [fine-earth bulk density]
M [TO]	= oven-dry mass of total soil arising from M [TF]
D [TO]	= mass of oven-dry total soil per m^3 [total soil bulk density]
M [FF]/ha	= field-moist mass of fine-earth per hectare
W	= moisture content [oven-dry mass fraction basis]

PLOT CODE	LAYERS	SUM L	SUM L (a)	n	Mean L(a)	d	M[BTF]	M[LTF]	M[TF]	M[ATF]	M[ASA]	M[LFO]	M[LSO]
		m	m		m	m	kg	kg	kg	kg	kg	kg	kg
	TOP	1.170	1.170	9	0.130	0.0655	3.241	1.201	4.442	3.241	0.000	1.032	0.000
ABF 1	MIDDLE	2.250	2.250	9	0.250	0.0655	10.585	1.256	11.841	10.585	0.000	1.212	0.000
	BOTTOM	0.550	1.080	9	0.120	0.0655	1.519	1.297	2.816	1.519	0.000	1.250	0.000
	TOP	1.650	1.650	9	0.183	0.0910	8.887	1.328	10.215	8.887	0.974	0.530	0.146
ABF 2	MIDDLE	1.445	1.445	9	0.161	0.0910	12.103	1.580	13.683	12.103	4.702	0.612	0.498
	BOTTOM	1.190	1.405	9	0.156	0.0910	9.450	1.733	11.183	9.450	3.890	0.676	0.618
	TOP	1.310	1.310	9	0.146	0.0872	8.441	1.527	9.968	8.441	0.974	1.026	0.098
AE 1	MIDDLE	1.280	1.280	9	0.142	0.0872	11.003	1.963	12.966	11.003	3.325	1.222	0.449
	BOTTOM	1.210	1.910	9	0.212	0.0872	10.857	2.028	12.885	10.857	3.071	1.117	0.692
	TOP	0.890	0.890	7	0.127	0.0872	4.190	1.231	5.421	4.190	0.731	0.678	0.221
AE 2	MIDDLE	0.910	0.910	7	0.130	0.0872	5.453	1.895	7.348	5.453	2.273	0.743	0.823
	BOTTOM	1.110	1.700	7	0.243	0.0872	10.383	1.989	12.372	10.383	5.650	0.847	0.912
	TOP	0.740	0.740	6	0.123	0.0891	2.189	1.284	3.473	2.189	0.000	0.265	0.000
AWE 1	MIDDLE	0.910	0.910	6	0.152	0.0891	4.676	1.863	6.539	4.676	0.020	0.531	0.008
	BOTTOM	1.220	1.350	6	0.225	0.0891	9.423	2.473	11.896	9.423	1.686	1.349	0.442
	TOP	1.160	1.160	9	0.129	0.0872	4.420	0.798	5.218	4.420	0.173	0.646	0.000
BAL 1	MIDDLE	1.370	1.370	9	0.152	0.0872	8.217	1.433	9.650	8.217	0.456	1.147	0.091
	BOTTOM	1.110	1.270	9	0.141	0.0872	7.415	1.064	8.479	7.415	0.222	0.880	0.052
	TOP	0.980	0.980	9	0.109	0.0872	5.113	1.494	6.607	5.113	0.527	0.985	0.136
BCH 1	MIDDLE	1.270	1.270	9	0.141	0.0872	9.737	1.996	11.733	9.737	3.691	1.060	0.717
	BOTTOM	1.150	2.250	9	0.250	0.0872	11.078	2.113	13.191	11.078	6.178	0.895	1.016

PLOT CODE	LAYERS	SUM L m	SUM L (a) m	n	Mean L(a) m	d m	M[BTF] kg	M[LTF] kg	M[TF] kg	M[ATF] kg	M[ASA] kg	M[LFO] kg	M[LSO] kg
	TOP	1.084	1.084	9	0.120	0.0910	1.874	1.109	2.983	1.874	0.155	0.809	0.046
BCH 2	MIDDLE	1.050	1.050	9	0.117	0.0910	6.129	1.355	7.484	6.129	1.552	0.805	0.389
	BOTTOM	1.780	2.366	9	0.263	0.0910	14.058	1.761	15.819	14.058	7.085	0.914	0.657
	TOP	0.800	0.800	6	0.133	0.0891	2.587	1.214	3.801	2.585	1.341	0.480	0.493
CER 1	MIDDLE	0.895	0.895	6	0.149	0.0891	5.120	1.170	6.290	5.116	2.396	0.413	0.601
	BOTTOM	0.925	1.310	6	0.218	0.0891	6.778	1.449	8.227	6.775	4.272	0.368	0.963
	TOP	1.200	1.200	9	0.133	0.0872	7.253	1.687	8.940	4.507	2.720	0.840	0.557
CHT 1	MIDDLE	1.160	1.160	9	0.129	0.0872	8.934	2.040	10.974	5.748	2.133	1.085	0.635
	BOTTOM	2.140	2.140	9	0.238	0.0872	19.851	1.935	21.786	5.906	1.597	1.188	0.396
	TOP	1.215	1.215	9	0.135	0.0891	6.829	1.272	8.101	6.829	1.427	0.866	0.188
DEN 1	MIDDLE	1.360	1.360	9	0.151	0.0891	9.446	1.474	10.920	9.446	2.318	1.088	0.207
	BOTTOM	1.725	1.930	9	0.214	0.0891	14.611	1.809	16.420	14.611	5.720	1.029	0.637
	TOP	1.190	1.190	9	0.132	0.0891	4.342	1.233	5.575	4.342	0.412	0.727	0.242
DEN 2	MIDDLE	1.465	1.465	9	0.163	0.0891	12.004	1.522	13.526	12.004	3.860	0.903	0.423
	BOTTOM	1.825	1.850	9	0.206	0.0891	16.705	1.550	18.255	16.705	6.096	0.773	0.642
	TOP	1.350	1.350	9	0.150	0.0891	8.815	1.440	10.255	8.815	1.094	0.939	0.271
DEN 3	MIDDLE	1.510	1.510	9	0.168	0.0891	14.175	1.596	15.771	14.175	3.333	0.865	0.418
	BOTTOM	1.640	1.640	9	0.182	0.0891	17.327	1.743	19.070	17.327	5.545	0.998	0.609
	TOP	1.220	1.220	9	0.136	0.0891	8.514	1.401	9.915	8.514	0.390	1.125	0.123
DEN 4	MIDDLE	1.685	1.685	9	0.187	0.0891	16.309	1.778	18.087	16.309	1.466	1.323	0.326
	BOTTOM	1.515	1.600	9	0.178	0.0891	16.213	1.601	17.814	16.213	1.191	1.284	0.187

PLOT CODE	LAYERS	SUM L m	SUM L (a) m	n	Mean L(a) m	d m	M[BTF] kg	M[LTF] kg	M[TF] kg	M[ATF] kg	M[ASA] kg	M[LFO] kg	M[LSO] kg
DEN 5	TOP	1.435	1.435	9	0.159	0.0891	9.805	1.264	11.069	9.802	0.000	1.115	0.000
	MIDDLE	1.435	1.435	9	0.159	0.0891	12.834	1.516	14.350	6.832	0.000	1.345	0.000
	BOTTOM	1.625	1.630	9	0.181	0.0891	16.210	1.472	17.682	7.201	0.000	1.304	0.000
DEN 6	TOP	1.245	1.245	9	0.138	0.0891	7.724	1.268	8.992	7.721	1.520	0.981	0.092
	MIDDLE	1.425	1.425	9	0.158	0.0891	12.196	1.533	13.729	6.505	2.342	1.234	0.131
	BOTTOM	1.830	1.830	9	0.203	0.0891	17.708	1.525	19.233	9.001	3.048	1.184	0.199
DEN 7	TOP	0.830	0.830	9	0.092	0.0910	1.044	0.702	1.746	1.041	0.005	0.279	0.000
	MIDDLE	1.410	1.410	9	0.157	0.0910	9.025	1.521	10.546	4.643	2.229	0.862	0.337
	BOTTOM	1.960	2.260	9	0.251	0.0910	18.414	1.650	20.064	6.348	3.734	0.731	0.737
DOW 1	TOP	1.510	1.510	9	0.168	0.0891	8.171	1.147	9.318	5.811	0.527	0.925	0.028
	MIDDLE	1.380	1.380	9	0.153	0.0891	11.886	1.294	13.180	5.820	0.232	1.047	0.029
	BOTTOM	1.620	1.610	9	0.179	0.0891	15.296	1.061	16.357	5.718	0.089	0.850	0.027
DOW 2	TOP	1.310	1.310	9	0.146	0.0891	7.966	1.194	9.160	7.957	2.227	0.782	0.243
	MIDDLE	1.280	1.280	9	0.142	0.0891	10.201	1.336	11.537	5.968	1.500	0.803	0.396
	BOTTOM	1.910	1.910	9	0.212	0.0891	17.956	1.397	19.353	6.592	1.200	0.932	0.271
DOW 3	TOP	0.790	0.790	9	0.088	0.0891	1.193	0.483	1.676	1.193	0.000	0.255	0.000
	MIDDLE	1.590	1.590	9	0.177	0.0891	12.161	1.008	13.169	5.870	1.868	0.546	0.338
	BOTTOM	2.000	2.120	9	0.236	0.0891	20.781	1.562	22.343	6.809	2.868	0.811	0.642
DOW 4	TOP	0.670	0.670	9	0.074	0.0891	0.943	0.551	1.494	0.945	0.000	0.305	0.000
	MIDDLE	1.340	1.340	9	0.149	0.0891	10.976	1.119	12.095	5.783	0.378	1.004	0.037
	BOTTOM	2.400	2.490	9	0.277	0.0891	20.371	1.141	21.512	6.012	0.529	1.042	0.029

PLOT CODE	LAYERS	SUM L	SUM L (a)	n	Mean L(a)	d	M[BTF]	M[LTF]	M[TF]	M[ATF]	M[ASA]	M[LFO]	M[LSO]
		m	m		m	m	kg	kg	kg	kg	kg	kg	kg
	TOP	1.620	1.620	9	0.180	0.0891	10.091	1.261	11.352	5.538	0.309	0.970	0.099
DOW 5	MIDDLE	1.300	1.300	9	0.144	0.0891	9.861	1.544	11.405	6.052	1.589	0.902	0.491
	BOTTOM	1.580	1.580	9	0.176	0.0891	13.096	1.360	14.456	5.626	0.974	0.819	0.408
	TOP	1.400	1.400	9	0.156	0.0891	9.450	1.433	10.883	5.793	0.179	1.081	0.116
DOW 6	MIDDLE	1.325	1.325	9	0.147	0.0891	10.530	2.109	12.639	5.866	0.381	1.594	0.234
	BOTTOM	1.775	1.775	9	0.197	0.0891	17.175	1.349	18.524	5.828	0.098	1.113	0.027
	TOP	1.535	1.535	9	0.171	0.0910	11.678	1.709	13.387	4.833	0.914	1.108	0.234
DST 1	MIDDLE	1.425	1.425	9	0.158	0.0910	13.498	1.617	15.115	5.548	1.442	1.122	0.171
	BOTTOM	1.420	1.540	9	0.171	0.0910	13.623	1.593	15.216	6.115	1.468	1.159	0.152
	TOP	1.210	1.210	8	0.151	0.0872	3.719	1.132	4.851	3.719	0.949	0.659	0.224
GTN 1	MIDDLE	0.940	0.940	8	0.118	0.0872	3.943	4.029	7.972	3.943	2.245	1.592	1.998
	BOTTOM	0.310	1.850	8	0.231	0.0872	0.885	2.552	3.437	0.885	0.848	0.647	1.790
	TOP	1.150	1.150	9	0.128	0.0910	1.658	0.763	2.421	1.658	0.012	0.468	0.092
INV 1	MIDDLE	1.590	1.590	9	0.177	0.0910	13.141	1.913	15.054	13.141	3.728	1.277	0.560
	BOTTOM	1.360	1.760	9	0.196	0.0910	12.057	1.652	13.709	12.057	5.743	0.848	0.740
	TOP	0.600	0.600	7	0.086	0.0910	0.000	1.752	1.752	0.000	0.000	1.229	0.164
INV 2	MIDDLE	1.000	1.000	7	0.143	0.0910	5.867	1.468	7.335	5.867	3.027	0.738	0.597
	BOTTOM	1.405	1.900	7	0.271	0.0910	10.220	1.876	12.096	10.220	5.552	0.691	1.021
	TOP	1.000	1.000	9	0.111	0.0910	3.178	1.204	4.382	3.178	0.583	0.675	0.171
KCD 1	MIDDLE	1.180	1.180	9	0.131	0.0910	9.702	1.788	11.490	9.702	5.157	0.663	0.884
	BOTTOM	2.200	2.320	9	0.258	0.0910	19.061	2.224	21.285	19.061	8.381	0.780	1.154

PLOT CODE	LAYERS	SUM L	SUM L (a)	n	Mean L(a)	d	M[BTF]	M[LTF]	M[TF]	M[ATF]	M[ASA]	M[LFO]	M[LSO]
		m	m		m	m	kg	kg	kg	kg	kg	kg	kg
	TOP	1.160	1.160	9	0.129	0.0910	3.133	0.996	4.129	3.133	0.640	0.474	0.000
KCD 2	MIDDLE	1.160	1.160	9	0.129	0.0910	10.014	1.414	11.428	10.014	4.433	0.661	0.493
	BOTTOM	2.090	2.180	9	0.242	0.0910	19.010	1.729	20.739	19.010	7.591	0.654	0.820
	TOP	0.875	0.875	6	0.146	0.0891	3.852	1.631	5.483	3.852	0.452	0.734	0.191
KIN 1	MIDDLE	0.785	0.785	6	0.131	0.0891	5.552	1.836	7.388	5.552	1.491	0.838	0.493
	BOTTOM	1.270	1.340	6	0.223	0.0891	11.636	2.036	13.672	11.636	4.455	0.840	0.799
	TOP	0.630	0.630	6	0.105	0.0891	1.944	1.037	2.981	1.944	0.000	0.444	0.000
KIN 2	MIDDLE	0.700	0.700	6	0.117	0.0891	3.769	1.898	5.667	3.769	0.594	0.972	0.299
	BOTTOM	1.640	1.670	6	0.278	0.0891	13.696	2.667	16.363	13.696	3.578	1.336	0.697
	TOP	1.270	1.270	9	0.141	0.0910	6.441	1.724	8.165	6.441	0.378	1.106	0.036
LAK 1	MIDDLE	0.990	0.990	9	0.110	0.0910	6.980	1.935	8.915	6.980	0.466	1.256	0.166
	BOTTOM	2.020	2.240	9	0.249	0.0910	17.170	1.932	19.102	17.170	2.979	1.187	0.313
	TOP	1.380	1.380	9	0.153	0.0910	8.995	1.747	10.742	8.995	4.979	0.566	0.764
LAK 2	MIDDLE	1.260	1.260	9	0.140	0.0910	8.772	2.041	10.813	8.772	5.587	0.551	1.187
	BOTTOM	0.810	1.860	9	0.207	0.0910	4.971	2.256	7.227	4.971	2.944	0.625	1.350
	TOP	0.800	0.800	6	0.133	0.0910	3.846	1.865	5.711	3.846	2.442	0.493	1.134
LAK 3	MIDDLE	0.940	0.940	6	0.157	0.0910	6.135	1.932	8.067	6.135	4.211	0.535	1.202
	BOTTOM	0.960	1.260	6	0.210	0.0910	6.819	1.805	8.624	6.819	4.653	0.401	1.213
	TOP	1.080	1.080	9	0.120	0.0910	3.718	1.188	4.906	3.718	0.087	0.484	0.028
LCH 1	MIDDLE	1.010	1.010	9	0.112	0.0910	6.538	1.138	7.676	6.538	0.738	0.629	0.101
	BOTTOM	1.730	2.410	9	0.268	0.0910	11.427	1.253	12.680	11.427	1.335	0.615	0.097

PLOT CODE	LAYERS	SUM L m	SUM L (a) m	n	Mean L(a) m	d m	M[BTF] kg	M[LTF] kg	M[TF] kg	M[ATF] kg	M[ASA] kg	M[LFO] kg	M[LSO] kg
	TOP	0.695	0.695	9	0.077	0.0714	1.304	1.146	2.450	1.304	0.000	1.067	0.000
LND 1	MIDDLE	1.710	1.710	9	0.190	0.0714	8.855	1.440	10.295	8.855	0.000	1.426	0.000
	BOTTOM	1.130	2.100	9	0.233	0.0714	5.344	1.178	6.522	5.344	0.000	1.170	0.000
	TOP	1.085	1.085	9	0.121	0.0655	1.976	1.103	3.079	1.976	0.499	0.792	0.220
LND 2	MIDDLE	1.535	1.535	9	0.171	0.0655	6.712	1.286	7.998	6.712	0.043	1.268	0.000
	BOTTOM	1.400	1.880	9	0.209	0.0655	6.305	1.133	7.438	6.305	0.000	1.114	0.000
	TOP	1.320	1.320	9	0.147	0.0891	8.248	1.056	9.304	8.248	0.771	0.654	0.101
LOT 1	MIDDLE	1.315	1.315	9	0.146	0.0891	12.011	1.394	13.405	12.011	3.278	0.782	0.364
	BOTTOM	1.865	1.870	9	0.208	0.0891	18.744	1.496	20.240	18.744	7.542	0.777	0.523
	TOP	1.385	1.385	9	0.154	0.0891	7.428	1.239	8.667	7.428	2.746	0.532	0.380
LOT 2	MIDDLE	1.465	1.465	9	0.163	0.0891	13.411	1.548	14.959	13.411	7.779	0.391	0.952
	BOTTOM	1.530	1.650	9	0.183	0.0891	14.088	2.635	16.723	14.088	8.353	0.789	1.540
	TOP	0.755	0.755	9	0.084	0.0891	0.000	1.145	1.145	0.000	0.000	0.626	0.000
LWT 1	MIDDLE	1.260	1.260	9	0.140	0.0891	7.156	1.758	8.914	7.156	5.342	0.392	1.218
	BOTTOM	0.000	2.490	9	0.277	0.0891	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TOP	1.490	1.490	9	0.166	0.0891	8.388	1.432	9.820	8.384	2.574	0.710	0.343
LWT 2	MIDDLE	1.425	1.425	9	0.158	0.0891	11.445	1.603	13.048	6.916	2.420	0.566	0.795
	BOTTOM	1.335	1.590	9	0.177	0.0891	12.667	1.708	14.375	6.473	3.663	0.474	1.094
	TOP	1.060	1.060	9	0.118	0.0910	8.175	1.341	9.516	4.275	1.433	0.731	0.335
MCH 1	MIDDLE	1.375	1.375	9	0.153	0.0910	14.753	1.489	16.242	6.201	3.611	0.718	0.615
	BOTTOM	1.945	2.065	9	0.229	0.0910	23.110	2.028	25.138	5.549	4.190	0.699	1.206

PLOT CODE	LAYERS	SUM L	SUM L (a)	n	Mean L(a)	d	M[BTF]	M[LTF]	M[TF]	M[ATF]	M[ASA]	M[LFO]	M[LSO]
		m	m		m	m	kg	kg	kg	kg	kg	kg	kg
	TOP	1.455	1.455	9	0.162	0.0910	12.905	1.443	14.348	6.055	0.050	0.960	0.012
MCH 2	MIDDLE	1.205	1.205	9	0.134	0.0910	12.247	1.415	13.662	5.192	0.121	1.049	0.033
	BOTTOM	1.790	1.840	9	0.204	0.0910	20.161	1.467	21.628	6.327	0.114	1.150	0.026
	TOP	1.430	1.430	9	0.159	0.0910	8.091	1.008	9.099	3.389	0.620	0.523	0.119
MID 1	MIDDLE	1.360	1.360	9	0.151	0.0910	13.201	1.868	15.069	7.585	3.414	0.850	0.822
	BOTTOM	1.580	1.710	9	0.190	0.0910	16.844	1.344	18.188	11.089	5.559	0.739	0.471
	TOP	0.990	0.990	9	0.110	0.0910	3.110	1.102	4.212	3.110	0.120	0.885	0.076
MOR 1	MIDDLE	1.320	1.320	9	0.147	0.0910	8.236	1.373	9.609	8.236	1.651	0.981	0.290
	BOTTOM	0.840	2.190	9	0.243	0.0910	5.704	1.219	6.923	5.704	1.570	0.912	0.204
	TOP	0.610	0.610	9	0.068	0.0655	0.000	1.095	1.095	0.000	0.000	0.747	0.000
MOR 2	MIDDLE	1.105	1.105	9	0.123	0.0655	3.786	1.454	5.240	3.786	0.000	1.435	0.000
	BOTTOM	2.190	2.785	9	0.309	0.0655	10.174	1.481	11.655	10.174	0.000	1.465	0.000
	TOP	1.605	1.605	9	0.178	0.0910	7.275	1.503	8.778	7.275	1.958	0.904	0.320
MOR 3	MIDDLE	0.970	0.970	9	0.108	0.0910	6.630	1.438	8.068	6.630	2.433	0.873	0.324
	BOTTOM	1.675	1.925	9	0.214	0.0910	15.874	1.887	17.761	15.874	7.235	1.062	0.654
	TOP	0.460	0.460	9	0.051	0.0891	0.000	0.961	0.961	0.000	0.000	0.647	0.000
NEW 1	MIDDLE	1.575	1.575	9	0.175	0.0891	11.315	1.322	12.637	5.506	0.051	1.097	0.031
	BOTTOM	2.465	2.470	9	0.274	0.0891	22.745	1.274	24.019	5.789	0.042	1.079	0.012
	TOP	1.030	1.030	9	0.114	0.0910	8.080	1.161	9.241	3.706	0.207	0.872	0.070
NTH 1	MIDDLE	1.575	1.575	9	0.175	0.0910	16.205	1.359	17.564	5.406	0.557	1.015	0.159
	BOTTOM	1.820	1.895	9	0.211	0.0910	21.680	1.252	22.932	9.570	1.847	1.002	0.105

PLOT CODE	LAYERS	SUM L m	SUM L (a) m	n	Mean L(a) m	d m	M[BTF] kg	M[LTF] kg	M[TF] kg	M[ATF] kg	M[ASA] kg	M[LFO] kg	M[LSO] kg
	TOP	1.550	1.550	9	0.172	0.0910	11.473	0.926	12.399	7.224	0.020	0.617	0.006
NTH 2	MIDDLE	1.300	1.300	9	0.144	0.0910	13.380	1.437	14.817	8.682	0.328	1.052	0.029
	BOTTOM	1.580	1.650	9	0.183	0.0910	18.748	1.272	20.020	9.086	0.394	0.937	0.063
	TOP	1.610	1.610	9	0.179	0.0910	14.716	1.592	16.308	14.716	0.459	1.139	0.030
NYM 1	MIDDLE	1.375	1.375	9	0.153	0.0910	15.284	2.367	17.651	15.284	2.419	1.687	0.258
	BOTTOM	1.495	1.515	9	0.168	0.0910	16.767	2.055	18.822	16.767	5.461	1.460	0.262
	TOP	0.865	0.865	9	0.096	0.0872	0.000	2.434	2.434	0.000	0.000	1.597	0.000
SEA 1	MIDDLE	1.235	1.235	9	0.137	0.0872	7.093	1.914	9.007	7.093	0.435	1.515	0.156
	BOTTOM	1.290	2.400	9	0.267	0.0872	8.648	2.454	11.102	8.648	1.655	1.616	0.640
	TOP	1.070	1.070	9	0.119	0.0891	3.013	0.743	3.756	3.009	0.295	0.531	0.015
SEW 1	MIDDLE	1.315	1.315	9	0.146	0.0891	9.097	1.299	10.396	5.614	2.192	0.729	0.412
	BOTTOM	1.685	2.120	9	0.236	0.0891	12.856	1.289	14.145	7.761	3.848	0.600	0.539
	TOP	1.555	1.555	9	0.173	0.0910	12.663	1.434	14.097	12.663	1.633	0.995	0.178
SFD 1	MIDDLE	1.230	1.230	9	0.137	0.0910	13.153	1.597	14.750	13.153	3.318	1.002	0.436
	BOTTOM	1.695	1.715	9	0.191	0.0910	19.942	1.597	21.539	19.942	5.647	1.226	0.205
	TOP	0.980	0.980	9	0.109	0.0910	5.461	1.122	6.583	5.461	0.400	0.371	0.082
SNT 1	MIDDLE	1.530	1.530	9	0.170	0.0910	12.043	1.579	13.622	12.043	2.438	0.613	0.320
	BOTTOM	1.740	1.990	9	0.221	0.0910	14.380	1.531	15.911	14.380	4.774	0.534	0.508
	TOP	1.630	1.630	9	0.181	0.0910	11.757	1.238	12.995	6.341	0.464	0.840	0.003
SWD 1	MIDDLE	0.870	0.870	9	0.097	0.0910	7.997	1.280	9.277	4.557	0.076	1.019	0.006
	BOTTOM	1.680	2.000	9	0.222	0.0910	17.968	1.584	19.552	9.114	4.212	0.845	0.512

PLOT CODE	LAYERS	SUM L m	SUM L (a) m	n	Mean L(a) m	d m	M[BTF] kg	M[LTF] kg	M[TF] kg	M[ATF] kg	M[ASA] kg	M[LFO] kg	M[LSO] kg
	TOP	1.675	1.675	9	0.186	0.0910	13.772	1.420	15.192	7.777	1.399	1.034	0.282
SWD 2	MIDDLE	1.350	1.350	9	0.150	0.0910	12.552	1.436	13.988	6.949	1.495	1.101	0.257
	BOTTOM	1.050	1.475	9	0.164	0.0910	10.097	1.576	11.673	5.446	0.957	1.233	0.267
	TOP	1.495	1.495	9	0.166	0.0910	10.439	1.022	11.461	10.439	0.456	0.884	0.000
SWD 3	MIDDLE	1.165	1.165	9	0.129	0.0910	11.726	1.255	12.981	11.726	0.368	1.161	0.024
	BOTTOM	1.230	1.840	9	0.204	0.0910	11.722	1.205	12.927	11.722	0.404	1.103	0.035
	TOP	1.125	1.125	9	0.125	0.0910	7.777	1.282	9.059	4.369	0.893	0.643	0.319
SWP 1	MIDDLE	1.525	1.525	9	0.169	0.0910	13.677	1.741	15.418	5.730	2.039	0.746	0.709
	BOTTOM	1.735	1.850	9	0.206	0.0910	16.637	1.444	18.081	6.048	2.557	0.508	0.774
	TOP	1.090	1.090	9	0.121	0.0910	5.178	1.417	6.595	5.162	1.578	0.668	0.084
SWP 2	MIDDLE	1.145	1.145	9	0.127	0.0910	8.730	1.895	10.625	3.916	2.128	1.117	0.313
	BOTTOM	2.245	2.265	9	0.252	0.0910	21.680	2.263	23.943	5.607	2.594	1.195	0.578
	TOP	1.730	1.730	9	0.192	0.0910	11.693	1.375	13.068	4.521	2.178	0.599	0.408
SWP 3	MIDDLE	1.115	1.115	9	0.124	0.0910	11.358	1.761	13.119	4.388	2.767	0.503	1.110
	BOTTOM	1.515	1.655	9	0.184	0.0910	14.763	1.966	16.729	5.620	3.694	0.550	1.292
	TOP	0.780	0.780	6	0.130	0.0872	1.636	1.324	2.960	1.636	0.468	0.900	0.220
TAY 1	MIDDLE	0.810	0.810	6	0.135	0.0872	4.118	1.998	6.116	4.118	2.227	0.946	0.874
	BOTTOM	0.630	1.410	6	0.235	0.0872	3.939	2.391	6.330	3.939	1.856	1.066	1.182
	TOP	1.125	1.125	9	0.125	0.0910	8.475	1.713	10.188	8.475	1.713	1.101	0.291
TAY 2	MIDDLE	1.470	1.470	9	0.163	0.0910	14.307	1.651	15.958	14.307	4.559	0.959	0.507
	BOTTOM	1.870	1.905	9	0.212	0.0910	19.407	1.803	21.210	19.407	4.966	1.118	0.509

PLOT CODE	LAYERS	SUM L m	SUM L (a) m	n	Mean L(a) m	d m	M[BTF] kg	M[LTF] kg	M[TF] kg	M[ATF] kg	M[ASA] kg	M[LFO] kg	M[LSO] kg
	TOP	1.040	1.040	9	0.116	0.0891	5.186	0.851	6.037	5.186	0.321	0.753	0.006
THT 1	MIDDLE	2.640	2.768	9	0.308	0.0891	19.755	1.174	20.929	7.721	0.448	1.052	0.061
	BOTTOM	0.400	0.690	9	0.077	0.0891	5.775	1.126	6.901	5.773	0.689	1.008	0.072
	TOP	0.830	0.830	9	0.092	0.0891	0.885	0.802	1.687	0.882	0.000	0.555	0.000
THT 2	MIDDLE	1.660	1.660	9	0.184	0.0891	16.455	1.546	18.001	9.570	0.856	1.356	0.157
	BOTTOM	1.920	2.010	9	0.223	0.0891	17.473	1.492	18.965	9.670	0.930	1.338	0.092
	TOP	2.030	2.030	9	0.226	0.0891	20.003	1.124	21.127	7.313	0.800	0.944	0.057
THT 3	MIDDLE	2.200	2.200	9	0.244	0.0891	23.396	1.638	25.034	8.023	1.000	1.302	0.231
	BOTTOM	0.200	0.270	9	0.030	0.0891	0.000	2.345	2.345	0.000	0.000	1.429	0.742
	TOP	0.600	0.600	9	0.067	0.0891	1.015	0.609	1.624	1.012	0.000	0.345	0.000
THT 4	MIDDLE	1.260	1.260	9	0.140	0.0891	9.150	1.596	10.746	7.337	0.842	1.379	0.150
	BOTTOM	1.690	2.640	9	0.293	0.0891	15.908	1.750	17.658	8.786	1.782	1.363	0.317
	TOP	0.620	0.620	9	0.069	0.0891	1.316	0.689	2.005	1.313	0.000	0.370	0.000
THT 5	MIDDLE	1.120	1.120	9	0.124	0.0891	9.861	1.739	11.600	7.235	0.486	1.595	0.057
	BOTTOM	2.100	2.760	9	0.307	0.0891	20.065	1.668	21.733	9.895	0.763	1.491	0.131
	TOP	0.570	0.570	9	0.063	0.0891	1.565	0.945	2.510	1.555	0.000	0.552	0.000
THT 6	MIDDLE	1.910	1.910	9	0.212	0.0891	16.831	1.465	18.296	8.769	0.976	1.164	0.153
	BOTTOM	1.810	2.020	9	0.224	0.0891	17.028	1.325	18.353	8.865	1.314	1.098	0.145
	TOP	0.780	0.780	9	0.087	0.0891	0.858	0.422	1.280	0.861	0.000	0.204	0.000
WLD 1	MIDDLE	1.700	1.700	9	0.189	0.0891	12.051	1.002	13.053	5.842	0.202	0.701	0.047
	BOTTOM	1.960	2.020	9	0.224	0.0891	18.231	1.204	19.435	5.495	0.607	0.815	0.271

PLOT CODE	LAYERS	S	M[FF] kg	M[FO] kg	RATIO	D[FO] kg/m3	M[TO] kg	D[TO] kg/m3	M[FF]/ha kg/ha	W
	TOP	0.000	4.442	3.817	1.164	968.056	3.817	968.056	1464560	0.164
ABF 1	MIDDLE	0.000	11.841	11.426	1.036	1506.920	11.426	1506.920	3904065	0.036
	BOTTOM	0.000	2.816	2.714	1.038	1464.236	2.714	1464.236	1823150	0.038
	TOP	0.110	9.095	4.078	2.230	379.969	5.198	484.322	1553571	0.965
ABF 2	MIDDLE	0.380	8.483	4.798	1.768	510.478	9.998	1063.709	1449032	0.369
	BOTTOM	0.403	6.675	4.047	1.649	522.814	8.555	1105.196	1346199	0.307
	TOP	0.108	8.896	6.387	1.393	816.318	7.459	953.326	1654905	0.336
AE 1	MIDDLE	0.291	9.192	7.419	1.239	970.434	11.193	1464.077	1709969	0.158
	BOTTOM	0.292	9.122	7.627	1.196	1055.291	11.390	1575.970	2678653	0.131
	TOP	0.176	4.469	3.000	1.490	564.351	3.952	743.440	1068890	0.372
AE 2	MIDDLE	0.421	4.252	2.947	1.443	542.209	6.043	1111.823	1016989	0.216
	BOTTOM	0.530	5.810	4.569	1.272	689.194	11.131	1678.964	2128261	0.111
	TOP	0.000	3.473	0.717	4.845	155.329	0.717	155.329	928222	3.845
AWE 1	MIDDLE	0.004	6.511	1.864	3.493	328.439	1.892	333.374	1740183	2.457
	BOTTOM	0.179	9.768	6.488	1.506	852.798	8.616	1132.510	2888862	0.381
	TOP	0.033	5.045	4.084	1.235	589.459	4.257	614.429	938511	0.226
BAL 1	MIDDLE	0.057	9.103	7.780	1.170	950.814	8.327	1017.662	1693413	0.159
	BOTTOM	0.032	8.205	7.135	1.150	1076.164	7.409	1117.493	1746376	0.144
	TOP	0.100	5.944	4.311	1.379	736.563	4.974	849.831	1105750	0.328
BCH 1	MIDDLE	0.376	7.325	6.071	1.207	800.313	10.479	1381.424	1362655	0.120
	BOTTOM	0.545	5.997	4.893	1.226	712.317	12.087	1759.671	2182715	0.091

PLOT CODE	LAYERS	S	M[FF] kg	M[FO] kg	RATIO	D[FO] kg/m3	M[TO] kg	D[TO] kg/m3	M[FF]/ha kg/ha	W
	TOP	0.067	2.782	2.117	1.314	300.272	2.318	328.778	475210	0.287
BCH 2	MIDDLE	0.259	5.543	4.619	1.200	676.309	6.560	960.498	946833	0.141
	BOTTOM	0.489	8.077	6.687	1.208	577.535	14.429	1246.193	1833890	0.096
	TOP	0.483	1.966	1.309	1.502	262.355	3.144	630.190	525439	0.209
CER 1	MIDDLE	0.477	3.291	2.389	1.378	428.014	5.388	965.334	879613	0.167
	BOTTOM	0.637	2.990	2.264	1.321	392.514	7.501	1300.398	1131784	0.097
	TOP	0.552	4.006	2.978	1.345	415.458	7.912	1103.886	745186	0.130
CHT 1	MIDDLE	0.360	7.024	5.424	1.295	782.859	9.374	1353.011	1306609	0.171
	BOTTOM	0.265	16.022	12.368	1.295	967.627	18.132	1418.561	2980584	0.202
	TOP	0.199	6.486	5.182	1.252	683.892	6.797	897.047	1155667	0.192
DEN 1	MIDDLE	0.231	8.395	7.209	1.165	850.027	9.734	1147.755	1495811	0.122
	BOTTOM	0.387	10.063	8.835	1.139	821.343	15.192	1412.308	2006095	0.081
	TOP	0.117	4.921	3.610	1.363	486.481	4.264	574.612	876818	0.307
DEN 2	MIDDLE	0.317	9.243	7.595	1.217	831.312	11.878	1300.134	1646906	0.139
	BOTTOM	0.369	11.517	9.805	1.175	861.526	16.543	1453.587	2080195	0.104
	TOP	0.133	8.890	7.141	1.245	848.238	8.506	1010.380	1584009	0.206
DEN 3	MIDDLE	0.238	12.020	8.826	1.362	937.339	12.577	1335.693	2141709	0.254
	BOTTOM	0.323	12.916	11.367	1.136	1111.476	17.521	1713.220	2301357	0.088
	TOP	0.052	9.402	8.276	1.136	1087.879	8.789	1155.309	1675237	0.128
DEN 4	MIDDLE	0.099	16.295	14.847	1.098	1413.013	16.639	1583.557	2903423	0.087
	BOTTOM	0.077	16.436	14.925	1.101	1579.783	16.303	1725.643	3092854	0.093

PLOT CODE	LAYERS	S	M[FF] kg	M[FO] kg	RATIO	D[FO] kg/m3	M[TO] kg	D[TO] kg/m3	M[FF]/ha kg/ha	W
	TOP	0.000	11.069	9.764	1.134	1091.146	9.764	1091.146	1972261	0.134
DEN 5	MIDDLE	0.000	14.350	12.731	1.127	1422.727	12.731	1422.727	2556865	0.127
	BOTTOM	0.000	17.682	15.664	1.129	1545.775	15.664	1545.775	3160251	0.129
	TOP	0.179	7.379	6.156	1.199	792.889	7.768	1000.597	1314854	0.158
DEN 6	MIDDLE	0.329	9.207	8.104	1.136	911.952	12.626	1420.823	1640503	0.087
	BOTTOM	0.322	13.038	11.641	1.120	1020.121	17.837	1563.021	2323016	0.078
	TOP	0.003	1.741	0.692	2.516	128.161	0.697	129.090	297388	1.505
DEN 7	MIDDLE	0.443	5.876	4.278	1.374	466.457	8.948	975.601	1003766	0.179
	BOTTOM	0.577	8.496	6.802	1.249	533.525	18.370	1440.904	1673300	0.092
	TOP	0.083	8.549	7.067	1.210	750.494	7.836	832.164	1523245	0.189
DOW 1	MIDDLE	0.038	12.677	10.493	1.208	1219.266	10.995	1277.694	2258806	0.199
	BOTTOM	0.016	16.092	13.228	1.216	1309.452	13.493	1335.692	2849539	0.212
	TOP	0.270	6.687	5.499	1.216	673.156	7.972	975.824	1191567	0.149
DOW 2	MIDDLE	0.257	8.577	7.327	1.171	917.942	10.287	1288.767	1528253	0.122
	BOTTOM	0.183	15.813	13.089	1.208	1098.918	16.629	1396.105	2817596	0.164
	TOP	0.000	1.676	0.885	1.894	179.613	0.885	179.613	298628	0.894
DOW 3	MIDDLE	0.320	8.961	7.303	1.227	736.507	11.511	1160.906	1596664	0.144
	BOTTOM	0.420	12.948	11.414	1.134	915.167	20.809	1668.471	2445462	0.074
	TOP	0.000	1.494	0.827	1.807	197.935	0.827	197.935	266199	0.807
DOW 4	MIDDLE	0.062	11.341	10.523	1.078	1259.316	11.277	1349.601	2020648	0.072
	BOTTOM	0.085	19.691	18.451	1.067	1232.843	20.272	1354.547	3640002	0.061

PLOT CODE	LAYERS	S	M[FF] kg	M[FO] kg	RATIO	D[FO] kg/m3	M[TO] kg	D[TO] kg/m3	M[FF]/ha kg/ha	W
	TOP	0.058	10.690	8.924	1.198	883.334	9.586	948.868	1904724	0.184
DOW 5	MIDDLE	0.270	8.325	7.131	1.167	879.657	10.211	1259.599	1483323	0.117
	BOTTOM	0.185	11.781	10.135	1.162	1028.635	12.810	1300.157	2099081	0.128
	TOP	0.037	10.475	8.598	1.218	984.837	9.006	1031.571	1866423	0.208
DOW 6	MIDDLE	0.073	11.721	9.964	1.176	1205.971	10.882	1317.065	2088446	0.161
	BOTTOM	0.017	18.208	15.330	1.188	1384.939	15.645	1413.470	3244313	0.184
	TOP	0.182	10.944	8.221	1.331	823.391	10.664	1068.014	1869495	0.255
DST 1	MIDDLE	0.243	11.436	8.873	1.289	957.289	12.553	1354.227	1953398	0.204
	BOTTOM	0.225	11.794	9.486	1.243	1026.947	12.908	1397.470	2184776	0.179
	TOP	0.242	3.678	2.669	1.378	369.357	3.842	531.663	769737	0.262
GTN 1	MIDDLE	0.532	3.729	2.923	1.276	520.617	7.166	1276.346	780411	0.112
	BOTTOM	0.768	0.799	0.678	1.178	366.400	3.316	1791.134	997901	0.036
	TOP	0.043	2.317	1.616	1.434	216.034	1.720	229.937	395781	0.408
INV 1	MIDDLE	0.285	10.766	10.161	1.060	982.475	14.449	1397.074	1839005	0.042
	BOTTOM	0.473	7.226	6.719	1.075	759.506	13.202	1492.344	1597351	0.038
	TOP	0.094	1.588	1.229	1.292	314.899	1.393	356.920	348757	0.258
INV 2	MIDDLE	0.494	3.711	3.144	1.180	483.393	6.768	1040.526	815012	0.084
	BOTTOM	0.543	5.523	4.464	1.237	488.407	11.037	1207.621	1640308	0.096
	TOP	0.172	3.628	2.371	1.530	364.453	3.125	480.369	619720	0.402
KCD 1	MIDDLE	0.526	5.449	3.996	1.363	520.656	10.037	1307.698	930776	0.145
	BOTTOM	0.448	11.750	8.565	1.372	598.545	18.100	1264.844	2116565	0.176

PLOT CODE	LAYERS	S	M[FF] kg	M[FO] kg	RATIO	D[FO] kg/m3	M[TO] kg	D[TO] kg/m3	M[FF]/ha kg/ha	W
	TOP	0.155	3.489	1.660	2.101	220.056	2.300	304.875	595977	0.795
KCD 2	MIDDLE	0.431	6.502	4.666	1.393	618.446	9.592	1271.287	1110646	0.191
	BOTTOM	0.406	12.328	8.870	1.390	652.426	17.281	1271.115	2196501	0.200
	TOP	0.117	4.840	2.467	1.962	452.136	3.110	569.979	1293578	0.763
KIN 1	MIDDLE	0.269	5.404	3.372	1.603	688.830	5.356	1094.124	1444317	0.379
	BOTTOM	0.384	8.418	5.716	1.473	721.794	10.970	1385.208	2373871	0.246
	TOP	0.000	2.981	1.276	2.336	324.881	1.276	324.881	796726	1.336
KIN 2	MIDDLE	0.158	4.774	2.902	1.645	664.815	3.795	869.389	1275938	0.493
	BOTTOM	0.261	12.088	8.198	1.475	801.584	12.473	1219.598	3289836	0.312
	TOP	0.051	7.751	5.079	1.526	614.763	5.493	664.878	1323995	0.487
LAK 1	MIDDLE	0.071	8.283	5.881	1.408	913.241	6.513	1011.382	1414869	0.369
	BOTTOM	0.172	15.810	11.591	1.364	882.176	14.883	1132.718	2994726	0.283
	TOP	0.535	4.999	2.878	1.737	320.655	8.621	960.435	853909	0.246
LAK 2	MIDDLE	0.626	4.039	2.606	1.550	317.957	9.380	1144.462	689926	0.153
	BOTTOM	0.594	2.933	2.023	1.450	384.017	6.317	1198.999	1150452	0.144
	TOP	0.626	2.135	1.440	1.483	276.700	5.016	963.892	547038	0.139
LAK 3	MIDDLE	0.671	2.654	1.945	1.364	318.108	7.358	1203.389	680018	0.096
	BOTTOM	0.680	2.758	1.868	1.476	299.169	7.734	1238.550	927499	0.115
	TOP	0.023	4.791	1.999	2.397	284.551	2.114	300.921	818379	1.321
LCH 1	MIDDLE	0.109	6.837	4.147	1.649	631.229	4.986	758.935	1167869	0.540
	BOTTOM	0.113	11.248	5.984	1.880	531.762	7.416	659.015	2676546	0.710

PLOT CODE	LAYERS	S	M[FF] kg	M[FO] kg	RATIO	D[FO] kg/m3	M[TO] kg	D[TO] kg/m3	M[FF]/ha kg/ha	W
	TOP	0.000	2.450	2.281	1.074	819.631	2.281	819.631	679800	0.074
LND 1	MIDDLE	0.000	10.295	10.195	1.010	1488.828	10.195	1488.828	2856546	0.010
	BOTTOM	0.000	6.522	6.478	1.007	1431.530	6.478	1431.530	3363075	0.007
	TOP	0.234	2.360	2.117	1.115	578.919	2.836	775.559	778109	0.086
LND 2	MIDDLE	0.005	7.955	7.844	1.014	1516.287	7.887	1524.599	2622822	0.014
	BOTTOM	0.000	7.438	7.313	1.017	1550.082	7.313	1550.082	3293174	0.017
	TOP	0.094	8.432	5.774	1.460	701.503	6.646	807.438	1502403	0.400
LOT 1	MIDDLE	0.272	9.763	7.412	1.317	903.911	11.054	1348.043	1739559	0.213
	BOTTOM	0.398	12.175	9.722	1.252	835.982	17.787	1529.446	2175142	0.138
	TOP	0.361	5.541	3.432	1.615	397.334	6.558	759.274	987288	0.322
LOT 2	MIDDLE	0.584	6.228	4.086	1.524	447.239	12.817	1402.946	1109697	0.167
	BOTTOM	0.592	6.830	4.921	1.388	515.811	14.814	1552.706	1312409	0.129
	TOP	0.000	1.145	0.626	1.829	132.961	0.626	132.961	204015	0.829
LWT 1	MIDDLE	0.736	2.354	1.709	1.378	217.484	8.269	1052.378	419433	0.078
	BOTTOM	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	TOP	0.297	6.902	4.500	1.534	484.287	7.418	798.361	1229749	0.324
LWT 2	MIDDLE	0.368	8.248	5.778	1.428	650.205	10.578	1190.340	1469662	0.234
	BOTTOM	0.575	6.113	4.719	1.295	566.857	12.981	1559.306	1297233	0.107
	TOP	0.323	6.441	4.680	1.376	678.762	7.755	1124.780	1100175	0.227
MCH 1	MIDDLE	0.567	7.036	5.780	1.217	646.256	14.986	1675.554	1201853	0.084
	BOTTOM	0.742	6.482	5.512	1.176	435.668	24.168	1910.265	1175514	0.040

PLOT CODE	LAYERS	S	M[FF] kg	M[FO] kg	RATIO	D[FO] kg/m3	M[TO] kg	D[TO] kg/m3	M[FF]/ha kg/ha	W
	TOP	0.008	14.229	9.546	1.491	1008.619	9.665	1021.147	2430615	0.485
MCH 2	MIDDLE	0.023	13.344	10.128	1.317	1292.183	10.447	1332.806	2279297	0.308
	BOTTOM	0.018	21.239	16.950	1.253	1455.729	17.339	1489.161	3729255	0.247
	TOP	0.176	7.500	4.412	1.700	474.334	6.011	646.259	1281085	0.514
MID 1	MIDDLE	0.449	8.305	6.749	1.231	762.907	13.513	1527.482	1418669	0.115
	BOTTOM	0.490	9.273	7.850	1.181	763.771	16.765	1631.205	1714299	0.085
	TOP	0.047	4.016	3.464	1.159	537.930	3.660	568.366	685997	0.151
MOR 1	MIDDLE	0.202	7.668	6.946	1.104	808.946	8.887	1035.006	1309817	0.081
	BOTTOM	0.256	5.149	4.626	1.113	846.727	6.400	1171.399	2293064	0.082
	TOP	0.000	1.095	0.747	1.466	363.381	0.747	363.381	361030	0.466
MOR 2	MIDDLE	0.000	5.240	5.172	1.013	1388.762	5.172	1388.762	1727667	0.013
	BOTTOM	0.000	11.655	11.529	1.011	1562.147	11.529	1562.147	4886772	0.011
	TOP	0.260	6.500	4.967	1.309	475.766	7.245	693.963	1110304	0.212
MOR 3	MIDDLE	0.342	5.311	4.162	1.276	659.636	6.919	1096.591	907204	0.166
	BOTTOM	0.444	9.872	8.503	1.161	780.410	16.392	1504.476	1937981	0.084
	TOP	0.000	0.961	0.647	1.485	225.551	0.647	225.551	171230	0.485
NEW 1	MIDDLE	0.011	12.501	10.623	1.177	1081.558	10.758	1095.385	2227447	0.175
	BOTTOM	0.007	23.842	20.385	1.170	1326.129	20.562	1337.645	4256751	0.168
	TOP	0.056	8.720	6.969	1.251	1040.223	7.491	1118.032	1489462	0.234
NTH 1	MIDDLE	0.104	15.735	13.309	1.182	1299.126	15.138	1477.620	2687848	0.160
	BOTTOM	0.187	18.643	16.286	1.145	1375.671	20.575	1737.979	3315714	0.115

PLOT CODE	LAYERS	S	M[FF] kg	M[FO] kg	RATIO	D[FO] kg/m3	M[TO] kg	D[TO] kg/m3	M[FF]/ha kg/ha	W
	TOP	0.003	12.361	8.290	1.491	822.240	8.328	825.985	2111497	0.489
NTH 2	MIDDLE	0.036	14.283	10.671	1.338	1261.959	11.206	1325.166	2439682	0.322
	BOTTOM	0.044	19.144	14.837	1.290	1443.645	15.713	1528.878	3414983	0.274
	TOP	0.030	15.819	11.535	1.371	1101.455	12.024	1148.149	2702138	0.356
NYM 1	MIDDLE	0.152	14.974	11.978	1.250	1339.198	14.655	1638.504	2557799	0.204
	BOTTOM	0.304	13.099	10.666	1.228	1096.833	16.389	1685.343	2267452	0.148
	TOP	0.000	2.434	1.597	1.524	309.108	1.597	309.108	452792	0.524
SEA 1	MIDDLE	0.066	8.416	7.253	1.160	983.226	7.844	1063.346	1565612	0.148
	BOTTOM	0.207	8.807	7.846	1.123	1018.271	10.141	1316.132	3048091	0.095
	TOP	0.083	3.446	2.513	1.371	376.655	2.824	423.173	613934	0.330
SEW 1	MIDDLE	0.381	6.432	5.286	1.217	644.653	9.250	1128.046	1146055	0.124
	BOTTOM	0.489	7.232	5.785	1.250	550.601	12.699	1208.525	1621214	0.114
	TOP	0.128	12.286	9.733	1.262	962.243	11.544	1141.286	2098645	0.221
SFD 1	MIDDLE	0.255	10.996	9.490	1.159	1186.141	13.244	1655.343	1878293	0.114
	BOTTOM	0.272	15.687	13.816	1.135	1253.119	19.668	1783.889	2711208	0.095
	TOP	0.073	6.101	2.176	2.803	341.418	2.658	417.030	1042148	1.476
SNT 1	MIDDLE	0.202	10.864	5.290	2.054	531.501	8.048	808.625	1855745	0.693
	BOTTOM	0.332	10.629	5.548	1.916	490.207	10.830	956.888	2076466	0.469
	TOP	0.066	12.132	8.252	1.470	778.246	9.115	859.670	2072286	0.426
SWD 1	MIDDLE	0.015	9.138	7.309	1.250	1291.487	7.448	1316.115	1560853	0.246
	BOTTOM	0.451	10.736	8.463	1.269	774.413	17.279	1581.138	2183223	0.132

PLOT CODE	LAYERS	S	M[FF] kg	M[FO] kg	RATIO	D[FO] kg/m3	M[TO] kg	D[TO] kg/m3	M[FF]/ha kg/ha	W
	TOP	0.182	12.433	11.296	1.101	1036.800	14.056	1290.066	2123681	0.081
SWD 2	MIDDLE	0.211	11.031	10.301	1.071	1173.030	13.258	1509.813	1884199	0.055
	BOTTOM	0.175	9.632	9.072	1.062	1328.337	11.114	1627.211	2311183	0.050
	TOP	0.040	11.005	9.519	1.156	978.862	9.975	1025.753	1879830	0.149
SWD 3	MIDDLE	0.030	12.589	11.873	1.060	1566.789	12.265	1618.518	2150402	0.058
	BOTTOM	0.034	12.488	11.773	1.061	1471.460	12.212	1526.329	3191054	0.059
	TOP	0.211	7.150	4.774	1.498	652.432	6.683	913.244	1221407	0.356
SWP 1	MIDDLE	0.362	9.842	7.115	1.383	717.212	12.690	1279.317	1681186	0.215
	BOTTOM	0.432	10.273	7.789	1.319	690.182	15.597	1382.019	1871129	0.159
	TOP	0.253	4.928	2.470	1.996	348.314	4.136	583.414	841800	0.594
SWP 2	MIDDLE	0.476	5.568	3.931	1.416	527.853	8.988	1206.833	951106	0.182
	BOTTOM	0.443	13.335	9.457	1.410	647.616	20.065	1374.033	2298133	0.193
	TOP	0.462	7.027	4.353	1.614	386.801	10.394	923.638	1200303	0.257
SWP 3	MIDDLE	0.631	4.847	3.745	1.294	516.347	12.017	1656.899	827917	0.092
	BOTTOM	0.657	5.733	4.679	1.225	474.755	15.674	1590.537	1069848	0.067
	TOP	0.232	2.272	1.852	1.227	397.565	2.540	545.242	633983	0.165
TAY 1	MIDDLE	0.507	3.015	2.538	1.188	524.503	5.639	1165.473	841312	0.085
	BOTTOM	0.480	3.292	2.903	1.134	771.385	5.941	1578.746	2055928	0.066
	TOP	0.197	8.184	6.337	1.292	865.908	8.341	1139.760	1397958	0.222
TAY 2	MIDDLE	0.317	10.892	9.131	1.193	954.891	14.197	1484.700	1860528	0.124
	BOTTOM	0.258	15.735	13.595	1.157	1117.645	19.070	1567.749	2738096	0.112

PLOT CODE	LAYERS	S	M[FF] kg	M[FO] kg	RATIO	D[FO] kg/m3	M[TO] kg	D[TO] kg/m3	M[FF]/ha kg/ha	W
	TOP	0.054	5.710	5.088	1.122	784.584	5.415	835.005	1017401	0.115
THT 1	MIDDLE	0.058	19.722	18.641	1.058	1132.297	19.848	1205.629	3684371	0.054
	BOTTOM	0.110	6.140	5.872	1.046	2354.018	6.633	2659.200	1887107	0.040
	TOP	0.000	1.687	1.167	1.445	225.556	1.167	225.556	300588	0.445
THT 2	MIDDLE	0.090	16.372	15.983	1.024	1544.023	17.612	1701.374	2917171	0.022
	BOTTOM	0.093	17.193	16.431	1.046	1372.353	18.204	1520.389	3206943	0.042
	TOP	0.106	18.882	16.705	1.130	1319.633	18.950	1496.994	3364333	0.115
THT 3	MIDDLE	0.126	21.887	20.254	1.081	1476.307	23.401	1705.704	3899777	0.070
	BOTTOM	0.316	1.603	1.429	1.122	1145.778	2.171	1740.717	385588	0.080
	TOP	0.000	1.624	0.920	1.765	245.887	0.920	245.887	289362	0.765
THT 4	MIDDLE	0.112	9.546	9.104	1.049	1158.624	10.304	1311.356	1700883	0.043
	BOTTOM	0.201	14.114	13.425	1.051	1273.875	16.969	1610.111	3928606	0.041
	TOP	0.000	2.005	1.077	1.862	278.486	1.077	278.486	357248	0.862
THT 5	MIDDLE	0.062	10.881	10.318	1.055	1477.298	11.037	1580.301	1938692	0.051
	BOTTOM	0.077	20.055	19.455	1.031	1485.597	21.133	1613.749	4696387	0.028
	TOP	0.000	2.510	1.466	1.712	412.482	1.466	412.482	447229	0.712
THT 6	MIDDLE	0.111	16.270	14.434	1.127	1211.891	16.461	1382.017	2898913	0.111
	BOTTOM	0.145	15.684	14.594	1.075	1293.000	17.263	1529.461	3118796	0.063
	TOP	0.000	1.280	0.619	2.069	127.213	0.619	127.213	228069	1.069
WLD 1	MIDDLE	0.036	12.589	9.241	1.362	871.698	9.705	915.438	2243147	0.345
	BOTTOM	0.118	17.150	14.981	1.145	1225.704	17.266	1412.645	3149333	0.126

APPENDIX 3
VEGETATION QUADRAT DATA

Appendix 3 - Example of spreadsheet calculating abundance-weighted site mean Ellenberg indicator values mR and mN from quadrat data

Ecological site classification: Indicator species analysis using cover fractions. SITE NAME:DEN4-BUNJUPS

Species name	% Cover in quadrat 1	2	3	4	5	6	7	8	9	Value R	Value N	% Cover x R indicator value 1	2	3	4	5	6	7	8	9
ACER PSEUDOPLATANUS			25				5	5		0	7	0	0	0	0	0	0	0	0	0
										0	0	0	0	0	0	0	0	0	0	0
LYSIMACHIA NEMORUM							3			7	7	0	0	0	0	0	0	21	0	0
CHRYSOSPLENIUM OPPOSITIFOLIUM						1				5	5	0	0	0	0	0	5	0	0	0
SCROPHULARIA NODOSA						1				6	7	0	0	0	0	0	6	0	0	0
DRYOPTERIS DILATATA					4	5	15	1		0	7	0	0	0	0	0	0	0	0	0
ANEMONE NEMOROSA				1						0	0	0	0	0	0	0	0	0	0	0
RUBUS FRUTICOSUS	40	70	60	80	50	30	25	40	40	5	6	200	350	300	400	250	150	125	200	200
EUPHORBIA AMYGDALOIDES	10						3			8	5	80	0	0	0	0	0	24	0	0
HYACINTHOIDES NON-SCRIPTA	30		5		10		5	20	10	7	6	210	0	35	0	70	0	35	140	70
DRYOPTERIS FILIX-MAS	10	10		3	40					5	6	50	50	0	15	200	0	0	0	0
DRYOPTERIS AFFINIS	5	10				12	10	25	20	5	6	25	50	0	0	0	60	50	125	100
HEDERA HELIX	5	5	4		4	4	3	5	5	0	0	0	0	0	0	0	0	0	0	0
OXALIS ACETOSELLA	5	4			3	4	2		3	4	6	20	16	0	0	12	16	8	0	12
CIRCAEA LUTETIANA	1						1			7	7	7	0	0	0	0	0	7	0	0
LONICERA PERICLYMENUM	1	1	3	5	3	1	1	5	2	3	4	3	3	9	15	9	3	3	15	6
VIOLA RIVINIANA	4									4	0	16	0	0	0	0	0	0	0	0
ATHYRIUM FILIX-FEMINA		5				15	8			0	6	0	0	0	0	0	0	0	0	0
ACER PSEUDOPLATANUS			3		1				1	0	7	0	0	0	0	0	0	0	0	0
GLECHOMA HEDERACEA			1			2	3			0	7	0	0	0	0	0	0	0	0	0
GERANIUM ROBERTIANUM							2			0	7	0	0	0	0	0	0	0	0	0
FRAXINUS EXCELSIOR							1			7	7	0	0	0	0	0	0	7	0	0
										0	0	0	0	0	0	0	0	0	0	0
DESCHAMPSIA CESPITOSA	25	15	15	4	15	20	15	20	20	0	3	0	0	0	0	0	0	0	0	0
LUZULA SYLVATICA									15	4	4	0	0	0	0	0	0	0	0	60
CAREX REMOTA						4				0	0	0	0	0	0	0	0	0	0	0
Total plant cover	136	120	116	93	130	99	102	121	116			611	469	344	430	541	240	280	480	448
Cover indicating for R-value	106	95	68	88	106	49	51	90	90			5.76	4.94	5.06	4.89	5.10	4.90	5.49	5.33	4.98
Cover indicating for N-value	127	115	112	92	126	91	99	116	111	Site mean WIV mR			5.16							
R-value effective fraction of cover	0.8	0.8	0.6	0.9	0.8	0.5	0.5	0.7	0.8	Standard error			0.30							
N-value effective fraction of cover	0.9	1.0	1.0	1.0	1.0	0.9	1.0	1.0	1.0	Reliability ratio			0.71							

Species name	% Cover x N indicator value 1	2	3	4	5	6	7	8	9	Ellenberg species no.
ACER PSEUDOPLATANUS	0	0	175	0	0	0	35	35	0	4
	0	0	0	0	0	0	0	0	0	
LYSIMACHIA NEMORUM	0	0	0	0	0	0	21	0	0	711
CHRYSOSPLENIUM OPPOSITIFOLIUM	0	0	0	0	0	5	0	0	0	299
SCROPHULARIA NODOSA	0	0	0	0	0	7	0	0	0	1065
DRYOPTERIS DILATATA	0	0	0	0	28	35	105	7	0	403
ANEMONE NEMOROSA	0	0	0	0	0	0	0	0	0	59
RUBUS FRUTICOSUS	240	420	360	480	300	180	150	240	240	991
EUPHORBIA AMYGDALOIDES	50	0	0	0	0	0	15	0	0	459
HYACINTHOIDES NON-SCRIPTA	180	0	30	0	60	0	30	120	60	582
DRYOPTERIS FILIX-MAS	60	60	0	18	240	0	0	0	0	404
DRYOPTERIS AFFINIS	30	60	0	0	0	72	60	150	120	400
HEDERA HELIX	0	0	0	0	0	0	0	0	0	548
OXALIS ACETOSELLA	30	24	0	0	18	24	12	0	18	821
CIRCAEA LUTETIANA	7	0	0	0	0	0	7	0	0	305
LONICERA PERICLYMENUM	4	4	12	20	12	4	4	20	8	692
VIOLA RIVINIANA	0	0	0	0	0	0	0	0	0	1286
ATHYRIUM FILIX-FEMINA	0	30	0	0	0	90	48	0	0	124
ACER PSEUDOPLATANUS	0	0	21	0	7	0	0	0	7	4
GLECHOMA HEDERACEA	0	0	7	0	0	14	21	0	0	531
GERANIUM ROBERTIANUM	0	0	0	0	0	0	14	0	0	524
FRAXINUS EXCELSIOR	0	0	0	0	0	0	7	0	0	487
	0	0	0	0	0	0	0	0	0	
DESCHAMPSIA CESPITOSA	75	45	45	12	45	60	45	60	60	378
LUZULA SYLVATICA	0	0	0	0	0	0	0	0	60	705
CAREX REMOTA	0	0	0	0	0	0	0	0	0	244
Total plant cover	676	643	650	530	710	491	574	632	573	
Cover indicating for R-value	5.32	5.59	5.80	5.76	5.63	5.40	5.80	5.45	5.16	
Cover indicating for N-value	Site mean WIV mN			5.55						
R-value effective fraction of cover	Standard error			0.23						
N-value effective fraction of cover	Reliability ratio			0.96						

Botanical listing of species encountered

	SPECIES [SCIENTIFIC NAME]	AUTHOR	SPECIES [ENGLISH COMMON NAME]	SPECIES CODE
1	ABIES GRANDIS	(DOUGLAS ex. D. DON) LINDLEY	Grand fir	ABIEGRAN
2	ACER CAMPESTRE	L.	Field maple	ACERCAMP
3	ACER PSEUDOPLATANUS	L.	Sycamore	ACERPSEU
4	AGROSTIS CAPILLARIS	L.	Common bent	AGROCAPI
5	AGROSTIS STOLONIFERA	L.	Creeping bent	AGROSTOL
6	AJUGA REPTANS	L.	Bugle	AJUGREPT
7	ALLIUM URSINUM	L.	Ramsons/ Wild garlic	ALLIURSI
8	ANEMONE NEMOROSA	L.	Wood anemone	ANEMNEMO
9	ANGELICA SYLVESTRIS	L.	Wild angelica	ANGESYLV
10	ANISANTHA STERILIS	(L.) NEVSKI	Barren brome	ANISSTER
11	ANTHOXANTHUM ODORATUM	L.	Sweet vernal grass	ANTHODOR
12	ARCTIUM MINUS	(HILL) BERNH.	Lesser burdock	ARCTMINU
13	ARRHENATHERUM ELATIUS	(L.) P. BEAUV.	False oat-grass	ARRHELAT
14	ARUM MACULATUM	L.	Lords-and-ladies	ARUMMACU
15	ATHYRIUM FILIX-FEMINA	(L.) ROTH.	Lady-fern	ATHYFILI
16	BETULA PENDULA	ROTH.	Silver birch	BETUPEND
17	BETULA PUBESCENS	EHRH.	Downy birch	BETUPUBE
18	BLECHNUM SPICANT	(L.) ROTH.	Hard-fern	BLECSPIC
19	BRACHYPODIUM SYLVATICUM	(HUDSON) P. BEAUV.	False brome	BRACSYLV
20	BROMOPSIS RAMOSA	(HUDSON) HOLUB.	Hairy-brome	BROMRAMO
21	CALLUNA VULGARIS	(L.) HULL	Heather	CALLVULG
22	CARDAMINE FLEXUOSA	WITH.	Wavy bitter-cress	CARDFLEX
23	CAREX ARENARIA	L.	Sand sedge	CAREAREN
24	CAREX BINERVIS	SMITH	Green-ribbed sedge	CAREBINE
25	CAREX LAEVIGATA	SMITH	Smooth-stalked sedge	CARELAEV
26	CAREX REMOTA	L.	Remote sedge	CAREREMO
27	CAREX SYLVATICA	HUDSON	Wood-sedge	CARESYLV
28	CARPINUS BETULUS	L.	Hornbeam	CARPBETU
29	CASTANEA SATIVA	MILLER	Sweet chestnut	CASTSATI
30	CENTAUREA NIGRA	L.	Common knapweed	CENTNIGR
31	CERASTIUM FONTANUM	BAUMG.	Common mouse-ear	CERAFONT
32	CERASTIUM SEMIDECANDRUM	L.	Little mouse-ear	CERASEMI
33	CHAMAECYPARIS LAWSONIANA	(A. MURRAY) PARL.	Lawson's cypress	CHAMLAWS
34	CHAMERION ANGUSTIFOLIUM	(L.) HOLUB.	Rosebay willowherb	CHAMANGU
35	CHRYSOSPLENIUM OPPOSITIFOLIUM	L.	Opposite-leaved golden-saxifrage	CHRYOPPO
36	CIRCAEA LUTETIANA	L.	Enchanter's nightshade	CIRCLUTE
37	CIRSIUM ARVENSE	(L.) SCOP.	Creeping thistle	CIRSARVE
38	CIRSIUM PALUSTRE	(L.) SCOP.	Marsh thistle	CIRSPALU
39	CONIUM MACULATUM	L.	Hemlock	CONIMACU
40	CONOPODIUM MAJUS	(GOUAN) LORET	Pignut	CONOMAJU
41	CORYDALIS CLAVICULATA	(L.) LIDEN	Climbing corydalis	CORYCLAV
42	CORYLUS AVELLANA	L.	Hazel	CORYAVEL
43	CRATAEGUS MONOGYNA	JACQ.	Hawthorn	CRATMONO
44	CYTISUS SCOPARIUS	(L.) LINK	Broom	CYTISCOP

Botanical listing of species encountered

	SPECIES [SCIENTIFIC NAME]	AUTHOR	SPECIES [ENGLISH COMMON NAME]	SPECIES CODE
45	DACTYLIS GLOMERATA	L.	Cock's-foot	DACTGLOM
46	DESCHAMPSIA CESPITOSA	(L.) P. BEAUV.	Tufted hair-grass	DESCCESP
47	DESCHAMPSIA FLEXUOSA	(L.) TRIN.	Wavy hair-grass	DESCFLEX
48	DIGITALIS PURPUREA	L.	Foxglove	DIGIPURP
49	DRYOPTERIS AFFINIS	(LOWE) FRASER-JENKINS	Scaly male-fern	DRYOAFFI
50	DRYOPTERIS CARTHUSIANA	(VILLARS) H.P. FUCHS	Narrow buckler-fern	DRYOCART
51	DRYOPTERIS DILATATA	(HOFFM.) A. GRAY	Broad buckler-fern	DRYODILA
52	DRYOPTERIS FILIX-MAS	(L.) SCHOTT	Male-fern	DRYOFILI
53	EPILOBIUM HIRSUTUM	L.	Great willowherb	EPILHIRS
54	EPILOBIUM MONTANUM	L.	Broad-leaved willowherb	EPILMONT
55	EQUISETUM SYLVATICUM	L.	Wood horsetail	EQUISYLV
56	ERICA CINEREA	L.	Bell heather	ERICCINE
57	ERICA TETRALIX	L.	Cross-leaved heath	ERICTETR
58	ERIOPHORUM VAGINATUM	L.	Hare's-tail cottongrass	ERIOVAGI
59	EUPHORBIA AMYGDALOIDES	L.	Wood spurge	EUPHAMYG
60	FAGUS SYLVATICA	L.	Beech	FAGUSYLV
61	FESTUCA GIGANTEA	(L.) VILLARS	Giant fescue	FESTGIGA
62	FESTUCA OVINA	L.	Sheep's fescue	FESTOVIN
63	FESTUCA RUBRA	L.	Red fescue	FESTRUBR
64	FILIPENDULA ULMARIA	(L.) MAXIM	Meadowsweet	FILIULMA
65	FRAGARIA VESCA	L.	Wild strawberry	FRAGVESC
66	FRANGULA ALNUS	MILLER	Alder buckthorn	FRANALNU
67	FRAXINUS EXCELSIOR	L.	Ash	FRAXEXCE
68	GALEOPSIS TETRAHIT	L.	Common hemp-nettle	GALETETR
69	GALIUM APARINE	L.	Cleavers	GALIAPAR
70	GALIUM MOLLUGO	L.	Hedge bedstraw	GALIMOLL
71	GALIUM ODORATUM	(L.) SCOP.	Woodruff	GALIODOR
72	GALIUM SAXATILE	L.	Heath bedstraw	GALISAXA
73	GERANIUM ROBERTIANUM	L.	Herb-Robert	GERAROBE
74	GEUM URBANUM	L.	Wood avens	GEUMURBA
75	GLECHOMA HEDERACEA	L.	Ground-ivy	GLECHEDE
76	GOODYERA REPENS	(L.) R. BR.	Creeping lady's-tresses	GOODREPE
77	GYMNOCARPIUM DRYOPTERIS	(L.) NEWMAN	Oak fern	GYMNDRYO
78	HEDERA HELIX	L.	Ivy	HEDEHELI
79	HERACLEUM SPHONDYLIUM	L.	Hogweed	HERASPHO
80	HOLCUS LANATUS	L.	Yorkshire-fog	HOLCLANA
81	HOLCUS MOLLIS	L.	Creeping soft-grass	HOLCMOLLI
82	HYACINTHOIDES NON-SCRIPTA	(L.) CHOUARD ex. ROTHM.	Bluebell	HYACNONS
83	HYPERICHUM HIRSUTUM	L.	Hairy St.John's-wort	HYPEHIRS
84	HYPERICUM PULCHRUM	L.	Slender St.John's-wort	HYPEPULC
85	ILEX AQUIFOLIUM	L.	Holly	ILEXAQUI
86	JUNCUS CONGLOMERATUS	L.	Compact rush	JUNCCONG
87	JUNCUS EFFUSUS	L.	Soft-rush	JUNCEFFU
88	JUNCUS SQUARROSUS	L.	Heath rush	JUNCSQUA

Botanical listing of species encountered

	SPECIES [SCIENTIFIC NAME]	AUTHOR	SPECIES [ENGLISH COMMON NAME]	SPECIES CODE
89	LAMIASTRUM GALEOBDOLON	(L.) EHREND. & POLATSCHEK	Yellow archangel	LAMIGALE
90	LAMIUM ALBUM	L.	White dead-nettle	LAMIALBU
91	LAPSANA COMMUNIS	L.	Nipplewort	LAPSCOMM
92	LARIX KAEMPFERI	(LINDLEY) CARRIERE	Japanese larch	LARIKAEM
93	LATHYRUS LINIFOLIUS	(REICHARD) BAESSLER	Bitter-vetch	LATHLINI
94	LISTERA OVATA	(L.) R. BR.	Common tway-blade	LISTOVAT
95	LONICERA PERICLYMENUM	L.	Honeysuckle	LONIPERI
96	LOTUS CORNICULATUS	L.	Common bird's-foot trefoil	LOTUCORN
97	LOTUS ULIGINOSUS	SCHK.	Greater bird's-foot trefoil	LOTUULIG
98	LUZULA PILOSA	(L.) WILLD.	Hairy wood-rush	LUZUPILO
99	LUZULA SYLVATICA	(HUDSON) GAUDIN	Great wood-rush	LUZUSYLV
100	LYSIMACHIA NEMORUM	L.	Yellow pimpernel	LYSINEMO
101	MALUS SYLVESTRIS	(L.) MILLER	Crab apple	MALUSYLV
102	MELAMPYRUM PRATENSE	L.	Common cow-wheat	MELAPRAT
103	MELICA UNIFLORA	RETZ.	Wood melick	MELIUNIF
104	MERCURIALIS PERENNIS	L.	Dog's mercury	MERCPERI
105	MILIUM EFFUSUM	L.	Wood millet	MILIEFFU
106	MOLINIA CAERULEA	(L.) M0ENCH	Purple moor-grass	MOLICAER
107	MONTIA PERFOLIATA	(WILLD.)	Spring beauty	MONTPERF
108	MYOSOTIS ARVENSIS	(L.) HILL	Field forget-me-not	MYOSARVE
109	ORCHIS MASCULA	(L.) L.	Early-purple orchid	ORCHMASC
110	OXALIS ACETOSELLA	L.	Wood-sorrel	OXALACET
111	PHALARIS ARUNDINACEA	L.	Reed canary-grass	PHALARUN
112	PICEA ABIES	(L.) KARSTEN	Norway spruce	PICEABIE
113	PICEA SITCHENSIS	(BONG.) CARRIERE	Sitka spruce	PICESITC
114	PINUS CONTORTA	DOUGLAS ex. LOUDON	Lodgepole pine	PINUCONT
115	PINUS SYLVESTRIS	L.	Scots pine	PINUSYLV
116	PLANTAGO LANCEOLATA	L.	Ribwort plantain	PLANLANC
117	POLYPODIUM INTERJECTUM	SHIVAS	Intermediate polypody	POLYINTE
118	POLYSTICHUM ACULEATUM	(L.) ROTH.	Hard shield-fern	POLYACUL
119	POTENTILLA ERECTA	(L.) RAEUSCH.	Tormentil	POTEEREC
120	PRIMULA VERIS	L.	Cowslip	PRIMVERI
121	PRIMULA VULGARIS	HUDSON	Primrose	PRIMVULG
122	PRUNELLA VULGARIS	L.	Selfheal	PRUNVULG
123	PRUNUS AVIUM	(L.) L.	Wild cherry	PRUNAVIU
124	PSEUDOTSUGA MENZIESII	(MIRBEL) FRANCO	Douglas fir	PSEUMENZ
125	PTERIDIUM AQUILINUM	(L.) KUHN	Bracken	PTERAQUI
126	QUERCUS PETRAEA	(MATTUSCHKA) LIEBL.	Sessile oak	QUERPETR
127	QUERCUS ROBUR	L.	Pedunculate oak	QUERROBU
128	RANUNCULUS FICARIA	L.	Lesser celandine	RANUFICA
129	RANUNCULUS REPENS	L.	Creeping buttercup	RANUREPE
130	ROSA ARVENSIS	HUDSON	Field-rose	ROSAARVE
131	RUBUS CAESIUS	L.	Dewberry	RUBUCAES
132	RUBUS FRUTICOSUS	L.	Bramble	RUBUFRUT

Botanical listing of species encountered

	SPECIES [SCIENTIFIC NAME]	AUTHOR	SPECIES [ENGLISH COMMON NAME]	SPECIES CODE
133	RUBUS IDAEUS	L.	Raspberry	RUBUIDAE
134	RUBUS SAXATILIS	L.	Stone bramble	RUBUSAXA
135	RUMEX ACETOSELLA	L.	Sheep's sorrel	RUMEACET
136	RUMEX OBTUSIFOLIUS	L.	Broad-leaved dock	RUMEOBTU
137	RUMEX SANGUINEUS	L.	Wood dock	RUMESANG
138	SAMBUCUS NIGRA	L.	Elder	SAMBNIGR
139	SCROPHULARIA NODOSA	L.	Common figwort	SCRONODO
140	SENECIO SYLVATICUS	L.	Heath groundsel	SENESYLV
141	SILENE DIOICA	(L.) CLAIRV.	Red campion	SILEDIOI
142	SOLANUM DULCAMARA	L.	Bittersweet	SOLADULC
143	SOLIDAGO VIRGAUREA	L.	Goldenrod	SOLIVIRG
144	SORBUS AUCUPARIA	L.	Rowan	SORBAUCU
145	SORBUS TORMINALIS	(L.) CRANTZ.	Wild service-tree	SORBTORM
146	STACHYS SYLVATICA	L.	Hedge woundwort	STACSYLV
147	STELLARIA GRAMINEA	L.	Lesser stitchwort	STELGRAM
148	STELLARIA HOLOSTEA	L.	Greater stitchwort	STELHOLO
149	STELLARIA MEDIA	(L.) VILLARS	Common chickweed	STELMEDI
150	STELLARIA NEMORUM	L.	Wood stitchwort	STELNEMO
151	SUCCISA PRATENSIS	MOENCH	Devil's-bit scabious	SUCCPRAT
152	TARAXACUM OFFICINALE	WIGG.	Dandelion	TARAOFFI
153	TEUCRIUM SCORODONIA	L.	Wood sage	TEUCSCOR
154	THUJA PLICATA	DONN ex. D.DON	Western red-cedar	THUJPLIC
155	TRICHOPHORUM CESPITOSUM	(L.) HARTMAN	Deergrass	TRICCESP
156	TRIENTALIS EUROPAEA	L.	Chickweed wintergreen	TRIEEURO
157	TRISETUM FLAVESCENS	(L.) P. BEAUV.	Yellow oat-grass	TRISFLAV
158	TSUGA HETEROPHYLLA	(RAF.) SARG.	Western hemlock	TSUGHETE
159	ULEX EUROPAEUS	L.	Gorse	ULEXEURO
160	ULMUS GLABRA	HUDSON	Wych elm	ULMUGLAB
161	URTICA DIOICA	L.	Stinging nettle	URTIDIOI
162	VACCINIUM MYRTILLUS	L.	Bilberry	VACCMYRT
163	VACCINIUM VITIS-IDAEA	L.	Cowberry	VACCVITI
164	VACCINIUM ULIGINOSUM	L.	Bog bilberry	VACCULIG
165	VALERIANA OFFICINALIS	L.	Common valerian	VALEOFFI
166	VERONICA CHAMEADRYS	L.	Germander speedwell	VEROCHAM
167	VIBURNUM OPULUS	L.	Guelder-rose	VIBUOPUL
168	VICIA OROBUS	DC.	Wood bitter-vetch	VICIORUB
169	VIOLA PALUSTRIS	L.	Marsh violet	VIOLPALU
170	VIOLA RIVINIANA	REICHB.	Common dog-violet	VIOLRIVI

Species mean abundancies for each site [sites sorted by soil nutrient regime]

	SEA 1	INV 2	MOR 3	MOR 2	INV 1	SNT1	MOR 1	BAL 1	LWT 1	CER 1
CCA score	1.04	1.65	1.87	2.08	2.66	2.84	2.91	2.94	2.95	2.97
Species code										
ABIEGRAN							6.33			
ACERCAMP										
ACERPSEU										
AGROCAPI		21.22	0.33					2.67		4.00
AGROSTOL					0.33		0.44			
AJUGREPT		0.33								
ALLIURSI										
ANEMNEMO										
ANGESYLV										
ANISSTER										
ANTHODOR						0.33				
ARCTMINU										
ARRHELAT										
ARUMMACU										
ATHYFILI										
BETUPEND									9.89	
BETUPUBE	4.00	0.55		2.00	5.89					
BLECSPIC					1.11	3.00				
BRACSYLV										
BROMRAMO										
CALLVULG	52.78		76.67	72.22	64.44	8.11		25.56		
CARDFLEX										
CAREAREN				1.22						
CAREBINE			1.56							
CARELAEV										
CAREREMO										
CARESYLV										
CARPBETU										
CASTSATI										
CENTNIGR										
CERAFONT		1.00					0.44			
CERASEMI										
CHAMLAWS										
CHAMANGU										
CHRYOPPO										
CIRCLUTE										
CIRSARVE										
CIRSPALU										
CONIMACU										
CONOMAJU										
CORYCLAV										
CORYAVEL										
CRATMONO										
CYTISCOP		0.33								
DACTGLOM										
DESCCESP										
DESCFLEX	1.78	3.33			10.89	0.56	11.22	6.00	5.56	93.33
DIGIPURP										
DRYOAFFI									1.67	
DRYOCART										
DRYODILA		11.11			2.78		2.00		42.78	7.00
DRYOFILI		2.78			0.44	0.22				
EPILHIRS										
EPILMONT										
EQUISYLV										
ERICCINE			2.11		1.89		50.00			
ERICTETR										
ERIOVAGI										
EUPHAMYG										
FAGUSYLV		0.11								
FESTGIGA										
FESTOVIN	0.22									
FESTRUBR										
FILIULMA										
FRAGVESC										
FRANALNU										
FRAXEXCE										
GALETETR										
GALIAPAR							0.22			
GALIMOLL										
GALIODOR										
GALISAXA								2.44	0.11	16.44
GERAROBE										
GEUMURBA										
GLECHEDE										
GOODREPE		0.33					0.11			
GYMNDRYO										
HEDEHELI									0.22	
HERASPHO										
HOLCLANA		3.78								0.22
HOLCMOLLI								2.11		
HYACNONS										
HYPEHIRS										
HYPEPULC										
ILEXAQUI										

Species mean abundancies for each site [sites sorted by soil nutrient regime]

	SEA 1	INV 2	MOR 3	MOR 2	INV 1	SNT1	MOR 1	BAL 1	LWT 1	CER 1
CCA score	1.04	1.65	1.87	2.08	2.66	2.84	2.91	2.94	2.95	2.97
Species code										
JUNCCONG										
JUNCEFFU			0.56			2.33				
JUNCSQUA			3.44							
LAMIGALE										
LAMIALBU										
LAPSCOMM										
LARIKAEM										
LATHLINI										
LISTOVAT										
LONIPERI										
LOTUCORN										
LOTUULIG										
LUZUPILO		2.11			0.33		0.11	1.33		
LUZUSYLV										
LYSINEMO										
MALUSYLV										
MELAPRAT						1.11				
MELIUNIF										
MERCPERI										
MILIEFFU										
MOLICAER						65.00				
MONTPERF										
MYOSARVE										
ORCHMASC										
OXALACET		8.33					1.89	2.67	3.44	
PHALARUN										
PICEABIE										
PICESITC			0.67						1.33	
PINUCONT			0.89							
PINUSYLV	11.33			0.11						
PLANLANC										
POLYINTE										
POLYACUL										
POTEEREC					1.00	4.67				
PRIMVERI										
PRIMVULG										
PRUNVULG										
PRUNAVIU										
PSEUMENZ		10.23							0.44	
PTERAQUI						3.00			58.33	
QUERPETR						0.11				
QUERROBU										
RANUFICA										
RANUREPE										
ROSAARVE										
RUBUCAES										
RUBUFRUT		0.67					1.22		7.00	1.11
RUBUIDAE										
RUBUSAXA										
RUMEACET										
RUMEOBTU										
RUMESANG										
SAMBNIGR										
SCRONODO										
SENESYLV										
SILEDIOI										
SOLADULC										
SOLIVIRG						0.22				
SORBAUCU	0.78	0.11			1.11	1.22	0.67	0.11	11.78	0.44
SORBTORM										
STACSYLV										
STELGRAM										
STELHOLO										
STELMEDI										
STELNEMO										
SUCCPRAT										
TARAOFFI										
TEUCSCOR		0.89								
THUJPLIC							0.11			
TRICCESP			6.89							
TRIEEURO					0.22					
TRISFLAV										
TSUGHETE		1.67					0.66			
ULEXEURO							0.33			
ULMUGLAB										
URTIDIOI										
VACCMYRT	4.67		1.22		9.11	1.00		5.11	14.33	1.67
VACCVITI	7.00									
VACCULIG						0.56				
VALEOFFI										
VEROCHAM										
VIBUOPUL										
VICIORUB										
VIOLPALU						0.33				
VIOLRIVI		5.89					0.33	0.22		

	KIN 1	LCH 1	SEW 1	KCD 2	KIN 2	LAK 3	GTN 1	BCH 2	WLD 1	KCD 1
CCA score	3.04	3.04	3.07	3.08	3.14	3.15	3.26	3.31	3.31	3.36
Species code										
ABIEGRAN										
ACERCAMP										
ACERPSEU										
AGROCAPI		8.89	0.11	0.56		0.50	6.11			0.22
AGROSTOL		7.11				2.83		0.56		
AJUGREPT										
ALLIURSI										
ANEMNEMO							13.33	1.44		
ANGESYLV										
ANISSTER										
ANTHODOR							0.44			
ARCTMINU										
ARRHELAT										
ARUMMACU										
ATHYFILI						1.67				
BETUPEND									10.56	
BETUPUBE	4.50						0.11			
BLECSPIC			0.89			0.50				
BRACSYLV										
BROMRAMO										
CALLVULG	42.38		2.56							
CARDFLEX										
CAREAREN										
CAREBINE	0.38									
CARELAEV										
CAREREMO										
CARESYLV										
CARPBETU										
CASTSATI										
CENTNIGR										
CERAFONT										
CERASEMI										
CHAMLAWS										
CHAMANGU										
CHRYOPPO										
CIRCLUTE										
CIRSARVE										
CIRSPALU										
CONIMACU										
CONOMAJU										
CORYCLAV						1.67				
CORYAVEL										
CRATMONO										
CYTISCOP										
DACTGLOM										
DESCCESP	0.25	7.78								
DESCFLEX	8.38	60.56	86.67	73.33	9.63	14.00	8.22	22.78		95.00
DIGIPURP						1.33		0.78		
DRYOAFFI	1.38				9.00	3.83				
DRYOCART										
DRYODILA	2.63	0.89	4.11	1.67	18.38	30.83		16.33		
DRYOFILI						5.50				
EPILHIRS										
EPILMONT										
EQUISYLV										
ERICCINE										
ERICTETR	0.88									
ERIOVAGI	0.25									
EUPHAMYG										
FAGUSYLV			0.33							
FESTGIGA										
FESTOVIN										
FESTRUBR										
FILIULMA										
FRAGVESC										
FRANALNU										
FRAXEXCE										
GALETETR										
GALIAPAR										
GALIMOLL										
GALIODOR										
GALISAXA		0.56	3.22	4.22	1.00		0.22	0.67		13.22
GERAROBE						0.67				
GEUMURBA										
GLECHEDE										
GOODREPE										
GYMNDRYO										
HEDEHELI										
HERASPHO										
HOLCLANA		3.89					0.22	6.67		
HOLCMOLLI			2.33	2.22			22.22	23.33		
HYACNONS										
HYPEHIRS										
HYPEPULC										
ILEXAQUI			1.22			2.17				

	KIN 1	LCH 1	SEW 1	KCD 2	KIN 2	LAK 3	GTN 1	BCH 2	WLD 1	KCD 1
CCA score	3.04	3.04	3.07	3.08	3.14	3.15	3.26	3.31	3.31	3.36
Species code										
JUNCCONG										
JUNCEFFU	1.75									
JUNCSQUA	0.50									
LAMIGALE										
LAMIALBU										
LAPSCOMM						0.33				
LARIKAEM										
LATHLINI										
LISTOVAT										
LONIPERI										
LOTUCORN										
LOTUULIG										
LUZUPILO				0.33			0.44	0.22		
LUZUSYLV	0.88			6.67	7.50					
LYSINEMO										
MALUSYLV										
MELAPRAT										
MELIUNIF										
MERCPERI										
MILIEFFU										
MOLICAER	4.38								4.56	
MONTPERF										
MYOSARVE										
ORCHMASC										
OXALACET		26.11		9.56	17.38	35.83	6.00	17.56		0.56
PHALARUN										
PICEABIE										
PICESITC		4.78								
PINUCONT										
PINUSYLV										
PLANLANC										
POLYINTE										
POLYACUL										
POTEEREC	0.38						1.78			
PRIMVERI										
PRIMVULG										
PRUNVULG										
PRUNAVIU										
PSEUMENZ						5.17				
PTERAQUI			5.33				20.33	16.67	60.56	
QUERPETR							0.11			
QUERROBU										
RANUFICA										
RANUREPE										
ROSAARVE										
RUBUCAES										
RUBUFRUT			0.11		0.88	18.33		2.00	0.22	
RUBUIDAE						0.83				
RUBUSAXA							11.44			
RUMEACET										
RUMEOBTU										
RUMESANG										
SAMBNIGR										
SCRONODO										
SENESYLV										
SILEDIOI										
SOLADULC										
SOLIVIRG										
SORBAUCU	0.38		0.56		0.25	0.33	0.67			
SORBTORM										
STACSYLV										
STELGRAM										
STELHOLO										
STELMEDI										
STELNEMO										
SUCCPRAT										
TARAOFFI										
TEUCSCOR						4.17				
THUJPLIC										
TRICCESP										
TRIEEURO								1.00		
TRISFLAV										
TSUGHETE										
ULEXEURO										
ULMUGLAB										
URTIDIOI										
VACCMYRT	10.50		2.89	1.11	6.50	0.67	11.11			
VACCVITI										
VACCULIG										
VALEOFFI										
VEROCHAM							2.67			
VIBUOPUL										
VICIORUB							0.44			
VIOLPALU		1.11								
VIOLRIVI						0.33	3.33			

	THT 2	DEN 2	SWD 2	SWD 3	DOW 3	NEW 1	SWP 2	LOT 2	LWT 2	MID 1
CCA score	3.43	3.49	3.52	3.59	3.65	3.69	3.83	3.91	3.95	3.97
Species code										
ABIEGRAN										
ACERCAMP										
ACERPSEU										
AGROCAPI									19.96	1.00
AGROSTOL			0.56							
AJUGREPT										
ALLIURSI										
ANEMNEMO										
ANGESYLV										
ANISSTER										
ANTHODOR									0.33	
ARCTMINU										
ARRHELAT										
ARUMMACU										
ATHYFILI									2.56	1.11
BETUPEND	1.11		1.12		0.11				0.11	
BETUPUBE				1.11						
BLECSPIC									1.67	
BRACSYLV										
BROMRAMO										
CALLVULG							1.78			
CARDFLEX										
CAREAREN										
CAREBINE									0.33	
CARELAEV										
CAREREMO										
CARESYLV										
CARPBETU										
CASTSATI				6.33						
CENTNIGR										
CERAFONT										
CERASEMI	0.11									
CHAMLAWS										
CHAMANGU			2.89	0.89						
CHRYOPPO										
CIRCLUTE										
CIRSARVE										
CIRSPALU										
CONIMACU										
CONOMAJU										
CORYCLAV										
CORYAVEL										
CRATMONO						1.67				
CYTISCOP										
DACTGLOM										
DESCCESP						2.11		0.56		
DESCFLEX	64.78	18.67	22.44	23.78		4.78	6.33	24.11	0.22	15.22
DIGIPURP				0.22				0.11		0.33
DRYOAFFI										
DRYOCART					0.56					
DRYODILA		2.22	16.56	1.11	2.11		1.00	41.33	46.67	3.22
DRYOFILI										
EPILHIRS										
EPILMONT										0.11
EQUISYLV										
ERICCINE										
ERICTETR										
ERIOVAGI										
EUPHAMYG										
FAGUSYLV							0.22			
FESTGIGA										
FESTOVIN										
FESTRUBR										
FILIULMA										
FRAGVESC										
FRANALNU										
FRAXEXCE										
GALETETR										
GALIAPAR			1.22							
GALIMOLL										
GALIODOR										
GALISAXA		0.33		1.00		0.67	0.89	0.78	0.67	0.33
GERAROBE										
GEUMURBA										
GLECHEDE										
GOODREPE										
GYMNDRYO										
HEDEHELI		7.00				5.22	6.78			
HERASPHO										
HOLCLANA										
HOLCMOLLI		31.67	11.44	0.33			0.56	28.89		9.67
HYACNONS		13.78								
HYPEHIRS										
HYPEPULC										
ILEXAQUI		0.56			1.00	0.89			2.56	

	THT 2	DEN 2	SWD 2	SWD 3	DOW 3	NEW 1	SWP 2	LOT 2	LWT 2	MID 1
CCA score	3.43	3.49	3.52	3.59	3.65	3.69	3.83	3.91	3.95	3.97
Species code										
JUNCCONG										
JUNCEFFU										0.22
JUNCSQUA										
LAMIGALE										
LAMIALBU										
LAPSCOMM										
LARIKAEM								0.11		
LATHLINI										
LISTOVAT										
LONIPERI					11.89	2.56	22.22			
LOTUCORN										
LOTUULIG										
LUZUPILO		0.22								
LUZUSYLV										
LYSINEMO										
MALUSYLV										
MELAPRAT										
MELIUNIF										
MERCPERI										
MILIEFFU										
MOLICAER					28.22	10.11				
MONTPERF										
MYOSARVE										
ORCHMASC										
OXALACET		1.78						5.33	4.67	
PHALARUN										
PICEABIE										
PICESITC								0.11	0.22	
PINUCONT										
PINUSYLV					0.11	0.11				
PLANLANC										
POLYINTE										
POLYACUL										
POTEEREC										
PRIMVERI										
PRIMVULG										
PRUNVULG										
PRUNAVIU										
PSEUMENZ								0.56	0.11	
PTERAQUI		92.22		15.33	73.33	71.67	57.78	43.67		83.33
QUERPETR		0.33					3.11			
QUERROBU			4.11							
RANUFICA										
RANUREPE										
ROSAARVE										
RUBUCAES										
RUBUFRUT		19.78	39.78	66.67	6.44	0.33	7.78		14.00	4.44
RUBUIDAE								0.22	0.44	
RUBUSAXA										
RUMEACET			7.67	0.11						
RUMEOBTU										
RUMESANG										
SAMBNIGR										
SCRONODO										
SENESYLV	0.67									
SILEDIOI										
SOLADULC										
SOLIVIRG										
SORBAUCU				0.33			6.00		1.55	
SORBTORM										
STACSYLV										
STELGRAM										
STELHOLO										
STELMEDI	3.22		3.44							
STELNEMO										
SUCCPRAT										
TARAOFFI										0.22
TEUCSCOR	1.67									
THUJPLIC										
TRICCESP										
TRIEEURO										
TRISFLAV										
TSUGHETE										
ULEXEURO										
ULMUGLAB										
URTIDIOI										
VACCMYRT							20.11		0.56	
VACCVITI										
VACCULIG										
VALEOFFI										
VEROCHAM										
VIBUOPUL										
VICIORUB										
VIOLPALU										
VIOLRIVI										

	MID 1	ABF 1	ABF 1	DOW 4	TAY 1	AWE 1	DEN 7	AE 2	THT 1	DEN 5	LAK 1
CCA score	3.97	3.99	3.99	4.01	4.08	4.15	4.15	4.20	4.20	4.37	4.39
Species code											
ABIEGRAN											
ACERCAMP											
ACERPSEU											0.33
AGROCAPI	1.00				0.50	7.63		0.56	1.11		
AGROSTOL			5.56		6.50						15.00
AJUGREPT					1.17						
ALLIURSI											
ANEMNEMO								0.11			
ANGESYLV											
ANISSTER											
ANTHODOR							0.67				
ARCTMINU											
ARRHELAT					0.33						
ARUMMACU											
ATHYFILI	1.11					0.88		2.89			
BETUPEND				0.56							
BETUPUBE		0.56							0.11		
BLECSPIC		4.00				1.00		0.44			
BRACSYLV											
BROMRAMO											
CALLVULG		1.33									
CARDFLEX											
CAREAREN			3.56								
CAREBINE		0.33									
CARELAEV						0.25					
CAREREMO											
CARESYLV											
CARPBETU											
CASTSATI											
CENTNIGR											0.33
CERAFONT											
CERASEMI											
CHAMLAWS											2.22
CHAMANGU			0.11						1.11		
CHRYOPPO											
CIRCLUTE											
CIRSARVE								0.22	0.89		
CIRSPALU											
CONIMACU											
CONOMAJU											
CORYCLAV							1.56				
CORYAVEL										51.12	
CRATMONO											
CYTISCOP									0.11		
DACTGLOM					0.33				0.33		
DESCCESP								1.22			23.56
DESCFLEX	15.22	63.89					4.44				10.00
DIGIPURP	0.33				0.67			1.56			
DRYOAFFI			3.44	0.44		3.38	1.67				
DRYOCART								0.11			
DRYODILA	3.22	1.00	72.22	2.22		6.75	23.33	3.33	1.11		7.22
DRYOFILI			0.56								0.89
EPILHIRS											
EPILMONT	0.11										
EQUISYLV											
ERICCINE		0.33									
ERICTETR											
ERIOVAGI											
EUPHAMYG											
FAGUSYLV										0.56	
FESTGIGA											
FESTOVIN					1.17						
FESTRUBR			0.22								
FILIULMA											
FRAGVESC											
FRANALNU											
FRAXEXCE										2.22	
GALETETR											
GALIAPAR											
GALIMOLL											
GALIODOR											
GALISAXA	0.33	0.67				0.50			13.56		0.67
GERAROBE											
GEUMURBA											
GLECHEDE											
GOODREPE											
GYMNDRYO											
HEDEHELI										8.33	
HERASPHO											
HOLCLANA			0.56			0.38		0.33	42.78		37.78
HOLCMOLLI	9.67				72.50		1.11			0.89	2.22
HYACNONS							2.56				
HYPEHIRS											
HYPEPULC								0.22			
ILEXAQUI							2.78				

	MID 1	ABF 1	ABF 1	DOW 4	TAY 1	AWE 1	DEN 7	AE 2	THT 1	DEN 5	LAK 1
CCA score	3.97	3.99	3.99	4.01	4.08	4.15	4.15	4.20	4.20	4.37	4.39
Species code											
JUNCCONG											
JUNCEFFU	0.22										1.11
JUNCSQUA											
LAMIGALE											
LAMIALBU											
LAPSCOMM											
LARIKAEM											
LATHLINI											
LISTOVAT											
LONIPERI				0.89			0.33			9.33	
LOTUCORN											
LOTUULIG											
LUZUPILO						0.38	0.33	0.67			
LUZUSYLV											
LYSINEMO											
MALUSYLV											
MELAPRAT										0.89	0.22
MELIUNIF											
MERCPERI											
MILIEFFU											
MOLICAER											
MONTPERF											
MYOSARVE											
ORCHMASC											
OXALACET					9.33	7.25	3.67	87.78			5.22
PHALARUN											
PICEABIE											
PICESITC		0.44									
PINUCONT											
PINUSYLV											
PLANLANC											
POLYINTE											
POLYACUL											
POTEEREC			0.11			0.38					
PRIMVERI											
PRIMVULG											
PRUNVULG											
PRUNAVIU											
PSEUMENZ											
PTERAQUI	83.33			78.89	11.67	5.25	37.78			18.89	
QUERPETR										0.89	
QUERROBU											
RANUFICA											
RANUREPE											0.44
ROSAARVE											
RUBUCAES											
RUBUFRUT	4.44		0.33	0.33		0.50	47.22	0.22	0.11	40.56	0.22
RUBUIDAE								1.33			
RUBUSAXA											
RUMEACET									3.89		
RUMEOBTU											
RUMESANG											
SAMBNIGR											
SCRONODO											
SENESYLV									0.22		
SILEDIOI											
SOLADULC											
SOLIVIRG										0.56	
SORBAUCU		0.44									
SORBTORM										0.33	
STACSYLV											
STELGRAM							1.33				
STELHOLO					1.17						
STELMEDI									0.22		
STELNEMO											
SUCCPRAT											
TARAOFFI	0.22							0.33			
TEUCSCOR								0.67		1.33	
THUJPLIC											
TRICCESP											
TRIEEURO											
TRISFLAV											
TSUGHETE											
ULEXEURO											
ULMUGLAB											
URTIDIOI									7.33		
VACCMYRT		25.56				1.63				0.44	0.33
VACCVITI											
VACCULIG											
VALEOFFI											
VEROCHAM					0.67						
VIBUOPUL											
VICIORUB											
VIOLPALU											
VIOLRIVI								0.89			

	LAK 2	AE 1	BCH 1	DOW 1	SWP 3	THT 5	THT4	LOT 1	DEN 6	DEN 1
CCA score	4.43	4.46	4.54	4.54	4.54	4.62	4.72	4.78	4.82	4.85
Species code										
ABIEGRAN										
ACERCAMP										
ACERPSEU	0.56		1.33			7.22		0.22		0.11
AGROCAPI	0.22		1.56	0.22	9.33			1.11	4.67	
AGROSTOL	40.56	23.33	6.67							
AJUGREPT								0.33	0.11	
ALLIURSI										
ANEMNEMO										0.33
ANGESYLV										
ANISSTER										
ANTHODOR										
ARCTMINU										
ARRHELAT										
ARUMMACU										
ATHYFILI	0.33		0.22					7.11	2.78	
BETUPEND				0.11			7.00		1.33	
BETUPUBE	0.22									
BLECSPIC			2.00							
BRACSYLV										
BROMRAMO										
CALLVULG										
CARDFLEX										
CAREAREN										
CAREBINE										
CARELAEV										
CAREREMO										
CARESYLV										
CARPBETU										
CASTSATI				9.55		79.22			2.22	
CENTNIGR										
CERAFONT										
CERASEMI										
CHAMLAWS										
CHAMANGU								0.22	0.22	
CHRYOPPO										
CIRCLUTE									1.22	
CIRSARVE	0.67									
CIRSPALU								0.22		
CONIMACU										
CONOMAJU										
CORYCLAV	2.44									
CORYAVEL					1.33				0.11	0.11
CRATMONO				1.11		0.22				
CYTISCOP										
DACTGLOM								1.11	0.67	
DESCCESP	0.33	5.22	1.67	2.22				4.00	0.56	
DESCFLEX	0.89									
DIGIPURP	1.00		1.22					0.56	3.11	
DRYOAFFI		6.11			3.67			2.22		3.67
DRYOCART		1.67		0.56						
DRYODILA	0.78	48.33	3.22	2.67	22.78	14.67	22.78	63.33	6.22	0.56
DRYOFILI									0.56	0.11
EPILHIRS										
EPILMONT									0.11	
EQUISYLV										
ERICCINE										
ERICTETR										
ERIOVAGI										
EUPHAMYG										
FAGUSYLV					1.56		2.78		3.11	
FESTGIGA										
FESTOVIN										
FESTRUBR										
FILIULMA										
FRAGVESC										
FRANALNU										
FRAXEXCE									0.56	
GALETETR										
GALIAPAR										
GALIMOLL										
GALIODOR										
GALISAXA										
GERAROBE										
GEUMURBA									0.11	
GLECHEDE										1.67
GOODREPE										
GYMNDRYO			11.67							
HEDEHELI				1.78	2.00				0.11	1.56
HERASPHO										
HOLCLANA	27.78					0.22		0.11		
HOLCMOLLI	0.56			2.00	1.11			0.56	68.89	
HYACNONS	12.78								20.89	3.11
HYPEHIRS										
HYPEPULC									0.56	
ILEXAQUI				3.22			7.89			
JUNCCONG									2.44	

	LAK 2	AE 1	BCH 1	DOW 1	SWP 3	THT 5	THT4	LOT 1	DEN 6	DEN 1
CCA score	4.43	4.46	4.54	4.54	4.54	4.62	4.72	4.78	4.82	4.85
Species code										
JUNCCONG									2.44	
JUNCEFFU	0.11		0.44						1.11	
JUNCSQUA										
LAMIGALE										
LAMIALBU										
LAPSCOMM										
LARIKAEM					0.11					
LATHLINI										
LISTOVAT										
LONIPERI				10.89					0.22	0.56
LOTUCORN										
LOTUULIG										
LUZUPILO			0.33							
LUZUSYLV									3.22	
LYSINEMO									2.11	
MALUSYLV										
MELAPRAT										
MELIUNIF										
MERCPERI										
MILIEFFU										
MOLICAER										
MONTPERF		4.11								
MYOSARVE										
ORCHMASC										
OXALACET	6.22	27.78	68.89	1.33	4.33			4.00	14.00	
PHALARUN										
PICEABIE								0.11		
PICESITC								0.22		
PINUCONT										
PINUSYLV				0.11						
PLANLANC										
POLYINTE										
POLYACUL										
POTEEREC										
PRIMVERI										
PRIMVULG										
PRUNVULG									0.11	
PRUNAVIU										
PSEUMENZ								0.22		
PTERAQUI	5.89			81.11	60.00		10.56			
QUERPETR	7.89									
QUERROBU						0.89	12.56		0.11	
RANUFICA										
RANUREPE			0.33						0.67	
ROSAARVE										
RUBUCAES										
RUBUFRUT	17.00	11.11		7.44	7.44	62.78	43.33		17.56	90.00
RUBUIDAE						1.11		4.11		
RUBUSAXA										
RUMEACET										
RUMEOBTU									0.11	
RUMESANG									0.11	
SAMBNIGR										
SCRONODO										
SENESYLV										
SILEDIOI										
SOLADULC										
SOLIVIRG										
SORBAUCU		1.11	1.00				1.67		0.22	
SORBTORM										
STACSYLV										
STELGRAM										
STELHOLO										
STELMEDI		2.89								
STELNEMO			0.22							
SUCCPRAT										
TARAOFFI										
TEUCSCOR	6.67					0.56				
THUJPLIC										
TRICCESP										
TRIEEURO										
TRISFLAV			0.22							
TSUGHETE										
ULEXEURO										
ULMUGLAB										1.11
URTIDIOI										
VACCMYRT				0.33						
VACCVITI										
VACCULIG										
VALEOFFI										
VEROCHAM										
VIBUOPUL										
VICIORUB										
VIOLPALU										
VIOLRIVI		0.22	0.22	0.11				0.22	0.33	

	THT 6	CHT 1	DOW 2	NTH 1	LND 1	SFD 1	SWP 1	DEN 3	NYM 1	MCH 1
CCA score	4.91	4.95	4.98	5.05	5.08	5.12	5.17	5.20	5.28	5.33
Species code										
ABIEGRAN										
ACERCAMP										
ACERPSEU						4.11	2.78	2.22		
AGROCAPI		6.78	0.22		0.56		0.11			1.00
AGROSTOL										
AJUGREPT							0.89			
ALLIURSI										
ANEMNEMO				7.56						35.00
ANGESYLV										
ANISSTER										
ANTHODOR			0.56							0.44
ARCTMINU										
ARRHELAT					0.22					
ARUMMACU										
ATHYFILI							5.78		6.00	
BETUPEND										
BETUPUBE										0.89
BLECSPIC							4.22			
BRACSYLV		13.44								3.22
BROMRAMO										
CALLVULG										
CARDFLEX									2.44	
CAREAREN					7.22					
CAREBINE										
CARELAEV										
CAREREMO										
CARESYLV										
CARPBETU										
CASTSATI										
CENTNIGR										
CERAFONT										
CERASEMI										
CHAMLAWS										
CHAMANGU					7.89		1.33		5.56	
CHRYOPPO										
CIRCLUTE				0.11						
CIRSARVE										
CIRSPALU							0.11		0.33	
CONIMACU										
CONOMAJU										4.89
CORYCLAV										
CORYAVEL				4.44			0.56			0.78
CRATMONO				1.00	0.78			0.44		
CYTISCOP										
DACTGLOM										0.89
DESCCESP		14.78								
DESCFLEX										1.00
DIGIPURP							0.44			
DRYOAFFI					1.11		1.11	0.22		
DRYOCART			0.22							
DRYODILA	1.67	0.22			25.33	26.00	25.33	3.78	21.67	
DRYOFILI			8.33	0.89	6.22	8.33		0.33		
EPILHIRS										
EPILMONT										
EQUISYLV										
ERICCINE										
ERICTETR										
ERIOVAGI										
EUPHAMYG		0.11								7.89
FAGUSYLV		4.89						0.56		
FESTGIGA									0.89	
FESTOVIN										
FESTRUBR										
FILIULMA										
FRAGVESC										0.89
FRANALNU										
FRAXEXCE							0.22		1.00	
GALETETR			4.33					1.44		
GALIAPAR									2.67	
GALIMOLL										
GALIODOR		1.00								
GALISAXA										
GERAROBE									1.22	
GEUMURBA										
GLECHEDE			6.00							
GOODREPE										
GYMNDRYO										
HEDEHELI							3.56	2.00		0.56
HERASPHO										
HOLCLANA	10.56		0.33							
HOLCMOLLI		7.78	15.33	8.33		4.33		27.78	9.44	4.78
HYACNONS			30.56	60.00		12.00		30.56		3.44
HYPEHIRS										
HYPEPULC							0.22			
ILEXAQUI		0.11			5.77		0.56			
JUNCCONG										

	THT 6	CHT 1	DOW 2	NTH 1	LND 1	SFD 1	SWP 1	DEN 3	NYM 1	MCH 1
CCA score	4.91	4.95	4.98	5.05	5.08	5.12	5.17	5.20	5.28	5.33
Species code										
JUNCCONG										
JUNCEFFU				0.44			0.44			
JUNCSQUA										
LAMIGALE										
LAMIALBU										
LAPSCOMM										
LARIKAEM										
LATHLINI										0.67
LISTOVAT										
LONIPERI			2.33	0.22				2.44		5.56
LOTUCORN					0.89					
LOTUULIG							0.22			
LUZUPILO		0.56					0.33			0.56
LUZUSYLV										
LYSINEMO										
MALUSYLV						0.56				
MELAPRAT										1.78
MELIUNIF		1.44								0.44
MERCPERI				10.22						
MILIEFFU						1.22				
MOLICAER										
MONTPERF										
MYOSARVE										
ORCHMASC										
OXALACET		11.33	1.00	0.44		3.22	0.44	2.22	10.56	
PHALARUN										
PICEABIE										
PICESITC										
PINUCONT										
PINUSYLV										
PLANLANC					0.44					
POLYINTE					1.11					
POLYACUL										
POTEEREC										
PRIMVERI										
PRIMVULG				0.67			0.33			
PRUNVULG										
PRUNAVIU										0.22
PSEUMENZ										
PTERAQUI	56.00			35.00		6.11		2.78		16.11
QUERPETR						0.33		2.22		
QUERROBU			0.33							
RANUFICA									0.22	
RANUREPE									0.33	
ROSAARVE										2.33
RUBUCAES					6.11					
RUBUFRUT	4.33	17.78	60.56	39.44	11.22	58.89	53.33	26.67	35.00	11.33
RUBUIDAE									5.00	
RUBUSAXA										
RUMEACET										
RUMEOBTU									0.67	
RUMESANG										
SAMBNIGR						5.44			3.67	
SCRONODO										
SENESYLV										
SILEDIOI						0.67			3.67	
SOLADULC										
SOLIVIRG										
SORBAUCU							0.33			
SORBTORM										
STACSYLV			0.33						1.11	
STELGRAM						0.33				
STELHOLO								3.56		
STELMEDI						2.33				
STELNEMO										
SUCCPRAT										2.22
TARAOFFI					0.44					0.78
TEUCSCOR						14.33	1.33			7.22
THUJPLIC										
TRICCESP										
TRIEEURO										
TRISFLAV										
TSUGHETE										
ULEXEURO										
ULMUGLAB										
URTIDIOI									9.22	
VACCMYRT										
VACCVITI										
VACCULIG										
VALEOFFI										
VEROCHAM										
VIBUOPUL							1.11			
VICIORUB										
VIOLPALU										
VIOLRIVI		0.22						0.22		4.00

	DEN 4	LND 2	DST 1	TAY 2	SWD 1	THT 3	DOW 5	MCH 2	NTH 2
CCA score	5.63	5.96	6.27	6.54	6.82	6.83	6.95	7.15	7.18
Species code									
ABIEGRAN									
ACERCAMP							0.44		
ACERPSEU	4.45			1.11	13.67	0.11	9.44		
AGROCAPI									
AGROSTOL	0.56						8.33		15.67
AJUGREPT			0.67				3.00	0.33	
ALLIURSI					18.33				
ANEMNEMO	0.11		7.00					0.89	
ANGESYLV					0.89			1.89	0.44
ANISSTER									0.33
ANTHODOR									0.44
ARCTMINU								0.89	
ARRHELAT									0.44
ARUMMACU			0.78		0.67			2.67	
ATHYFILI	3.11				0.89				
BETUPEND									
BETUPUBE									
BLECSPIC									
BRACSYLV		1.33	2.44		7.67	1.22	3.67	0.33	2.00
BROMRAMO					0.22			3.11	
CALLVULG									
CARDFLEX									
CAREAREN		0.44							
CAREBINE									
CARELAEV									
CAREREMO	0.44								
CARESYLV					0.89			1.44	
CARPBETU							0.55		
CASTSATI									
CENTNIGR									
CERAFONT									
CERASEMI									
CHAMLAWS									
CHAMANGU		2.11							3.67
CHRYOPPO	0.11								
CIRCLUTE	0.22		0.78				1.11	2.89	
CIRSARVE									15.89
CIRSPALU									
CONIMACU									2.89
CONOMAJU					0.78			0.33	
CORYCLAV									
CORYAVEL		0.89	0.33		15.11		3.22	20.00	
CRATMONO			0.33			0.44	0.22	2.78	0.67
CYTISCOP									
DACTGLOM						0.33			
DESCCESP	16.56				18.33			6.11	0.56
DESCFLEX									
DIGIPURP									
DRYOAFFI					0.67				
DRYOCART									
DRYODILA	2.78	26.67				0.56			
DRYOFILI	7.00	19.22					0.22	3.33	0.56
EPILHIRS									1.78
EPILMONT									
EQUISYLV		0.44							
ERICCINE									
ERICTETR									
ERIOVAGI									
EUPHAMYG	1.44								
FAGUSYLV			2.11	0.11					
FESTGIGA						0.33			0.44
FESTOVIN									
FESTRUBR									
FILIULMA					0.89			16.67	
FRAGVESC			0.44						
FRANALNU								8.33	
FRAXEXCE	0.11		2.67				17.67	37.59	
GALETETR									
GALIAPAR				1.00		37.78	8.44	5.44	10.33
GALIMOLL							0.33		
GALIODOR					6.89				
GALISAXA									
GERAROBE	0.22	0.22				0.11		0.22	
GEUMURBA						2.89	5.78	2.89	0.33
GLECHEDE	0.67				0.56	0.33	18.67	4.00	8.67
GOODREPE									
GYMNDRYO									
HEDEHELI	3.89	14.11	11.33			2.33	1.00		
HERASPHO					4.00				1.33
HOLCLANA									
HOLCMOLLI									
HYACNONS	8.89		74.44		5.67				
HYPEHIRS								0.44	
HYPEPULC									
ILEXAQUI			3.00						

	DEN 4	LND 2	DST 1	TAY 2	SWD 1	THT 3	DOW 5	MCH 2	NTH 2
CCA score	5.63	5.96	6.27	6.54	6.82	6.83	6.95	7.15	7.18
Species code									
JUNCCONG									
JUNCEFFU								0.33	1.67
JUNCSQUA									
LAMIGALE			0.33		0.22				
LAMIALBU			2.78				0.11		
LAPSCOMM						0.11			
LARIKAEM									
LATHLINI									
LISTOVAT								1.00	
LONIPERI	2.44				2.11			0.56	
LOTUCORN									
LOTUULIG									
LUZUPILO									
LUZUSYLV	1.67								
LYSINEMO	0.33								
MALUSYLV									
MELAPRAT									
MELIUNIF									
MERCPERI			6.67	20.56	41.00		37.22	46.89	14.44
MILIEFFU									
MOLICAER									
MONTPERF									
MYOSARVE									2.11
ORCHMASC								0.22	
OXALACET	2.33				2.56				
PHALARUN									21.89
PICEABIE									
PICESITC									
PINUCONT									
PINUSYLV									
PLANLANC									
POLYINTE									
POLYACUL								0.89	
POTEEREC									
PRIMVERI							1.44		
PRIMVULG								0.33	
PRUNVULG									
PRUNAVIU									
PSEUMENZ									
PTERAQUI								0.33	
QUERPETR									
QUERROBU									
RANUFICA					0.33			13.33	
RANUREPE						0.11			
ROSAARVE									0.89
RUBUCAES		3.67							
RUBUFRUT	48.33	60.56	0.33		11.67	7.78	1.67	9.11	3.89
RUBUIDAE					0.56				
RUBUSAXA									
RUMEACET									
RUMEOBTU								0.56	
RUMESANG							0.11		2.44
SAMBNIGR						0.33			14.44
SCRONODO	0.11						0.33		
SENESYLV									
SILEDIOI							1.11		
SOLADULC		0.22							
SOLIVIRG									
SORBAUCU									
SORBTORM									
STACSYLV					3.11	3.00	1.22	0.33	2.44
STELGRAM									
STELHOLO									
STELMEDI									1.00
STELNEMO									
SUCCPRAT									
TARAOFFI									
TEUCSCOR									
THUJPLIC									
TRICCESP									
TRIEEURO									
TRISFLAV									
TSUGHETE									
ULEXEURO									
ULMUGLAB									
URTIDIOI				61.67		54.44	18.11	0.78	19.56
VACCMYRT									
VACCVITI									
VACCULIG									
VALEOFFI								1.33	
VEROCHAM					1.78		1.11	1.22	
VIBUOPUL									
VICIORUB									
VIOLPALU									
VIOLRIVI	0.44	1.00	0.56				2.00		

APPENDIX 4
SOIL CHEMICAL DATA

PLOT CODE	LAYERS	pH [H2O]	pH [CaCl2]	EXCH.Ca kg/ha	EXCH. Mg kg/ha	EXCH. K kg/ha	TOTAL P kg/ha	AV NO3-N kg/ha	AV NH4-N kg/ha	MI NO3-N kg/ha	MI NH4-N kg/ha	L.O.I kg/ha
	TOP	4.1	3.4	615	140	50	495.8	0.88	5.86	0.59	74.40	93732
ABF 1	MIDDLE	5.7	5.4	1944	154	15	1213.1	4.68	0.00	3.90	12.49	15616
	BOTTOM	6.7	6.4	1181	60	11	597.4	4.01	0.00	0.00	2.19	7293
	TOP	3.7	3.0	96	109	49	269.6	5.90	16.78	0.00	79.85	142929
ABF 2	MIDDLE	3.9	3.8	14	8	8	297.5	8.40	5.51	0.29	27.24	63757
	BOTTOM	4.1	4.1	5	4	4	340.3	7.81	0.00	0.54	12.65	61925
	TOP	3.4	3.3	146	60	76	573.9	25.82	13.57	44.35	59.25	95984
AE 1	MIDDLE	3.9	3.6	62	25	26	488.6	4.10	2.05	9.58	19.49	53009
	BOTTOM	4.0	3.8	123	52	35	761.5	1.61	2.68	8.57	26.79	61609
	TOP	4.1	3.9	554	72	50	429.8	10.05	11.54	4.06	57.93	136818
AE 2	MIDDLE	4.5	4.3	393	35	23	372.2	4.88	0.81	9.36	3.66	83393
	BOTTOM	4.8	4.6	626	60	38	771.6	0.85	0.00	9.36	8.09	93643
	TOP	3.3	3.0	53	80	42	201.2	0.00	13.09	0.00	48.64	140162
AWE 1	MIDDLE	3.6	3.2	57	89	12	320.8	1.91	37.41	13.92	122.86	229704
	BOTTOM	3.9	3.6	41	34	39	594.8	1.73	8.96	4.33	48.82	161776
	TOP	3.8	3.5	248	86	80	185.4	0.00	9.01	1.31	42.61	106052
BAL 1	MIDDLE	3.9	4.1	78	42	39	276.4	4.74	2.03	7.11	18.63	77897
	BOTTOM	4.0	4.3	66	42	36	238.4	2.79	0.00	6.64	5.94	52391
	TOP	3.6	4.0	502	137	104	607.1	24.77	0.88	27.64	37.60	69662
BCH 1	MIDDLE	3.7	4.0	248	199	73	827.8	14.44	0.00	10.63	14.44	44968
	BOTTOM	3.9	4.2	415	425	101	1324.9	37.11	0.00	38.42	12.66	58933

PLOT CODE	LAYERS	pH [H2O]	pH [CaCl2]	EXCH.Ca kg/ha	EXCH. Mg kg/ha	EXCH. K kg/ha	TOTAL P kg/ha	AV NO3-N kg/ha	AV NH4-N kg/ha	MI NO3-N kg/ha	MI NH4-N kg/ha	L.O.I kg/ha
	TOP	3.3	3.1	155	67	73	153.0	11.21	35.64	25.28	64.25	74133
BCH 2	MIDDLE	3.1	3.5	0	16	36	238.3	10.60	0.76	32.19	6.82	75747
	BOTTOM	3.3	3.8	0	14	50	534.4	12.47	0.00	21.27	2.93	100864
	TOP	3.6	3.2	72	35	56	287.5	10.77	28.90	29.53	72.83	91426
CER 1	MIDDLE	3.6	3.7	2	3	19	365.8	3.25	0.53	7.30	6.77	86202
	BOTTOM	3.8	4.0	0	1	14	380.5	1.36	0.00	5.55	0.00	73566
	TOP	3.6	3.9	653	40	99	174.5	44.26	7.90	107.16	3.58	60360
CHT 1	MIDDLE	3.6	4.1	1011	67	72	306.7	8.88	4.70	11.24	11.76	20906
	BOTTOM	6.9	6.9	22658	232	67	885.8	3.58	6.56	10.73	28.02	89418
	TOP	3.5	3.3	213	53	107	347.1	28.66	9.59	81.01	21.03	64717
DEN 1	MIDDLE	3.7	3.5	48	17	73	343.0	8.38	0.00	22.44	5.53	49362
	BOTTOM	3.9	3.6	76	26	67	369.9	6.42	0.00	16.05	0.00	40122
	TOP	2.8	2.9	282	61	78	245.7	20.34	19.64	22.62	69.44	118370
DEN 2	MIDDLE	3.0	3.2	27	14	60	358.6	7.41	3.13	13.34	9.55	82345
	BOTTOM	3.1	3.7	16	7	54	469.3	6.45	3.54	12.27	0.00	58245
	TOP	3.0	3.4	153	49	147	405.9	37.70	35.32	77.14	65.42	79200
DEN 3	MIDDLE	3.3	3.6	38	15	89	279.9	13.06	7.28	17.13	14.35	53543
	BOTTOM	3.4	3.7	31	11	70	360.5	5.98	3.22	7.13	1.61	39123
	TOP	3.5	3.6	474	139	183	343.6	23.79	25.46	58.30	48.75	83762
DEN 4	MIDDLE	3.7	3.7	462	204	151	463.0	8.71	9.00	17.71	12.78	75489
	BOTTOM	3.7	3.6	534	314	177	440.9	4.33	9.90	4.64	14.85	55671

PLOT CODE	LAYERS	pH [H2O]	pH [CaCl2]	EXCH.Ca kg/ha	EXCH. Mg kg/ha	EXCH. K kg/ha	TOTAL P kg/ha	AV NO3-N kg/ha	AV NH4-N kg/ha	MI NO3-N kg/ha	MI NH4-N kg/ha	L.O.I kg/ha
	TOP	3.5	3.5	287	112	162	285.3	1.18	43.78	0.00	91.71	92696
DEN 5	MIDDLE	3.5	3.4	50	175	132	219.1	0.00	10.48	0.00	16.88	76706
	BOTTOM	3.5	3.5	189	590	210	252.0	0.00	9.80	0.00	12.96	94808
	TOP	3.0	3.4	178	76	81	285.2	23.67	8.68	64.56	20.51	86780
DEN 6	MIDDLE	3.3	3.4	13	17	54	248.4	6.73	3.94	13.94	8.20	65620
	BOTTOM	3.3	3.6	6	24	74	196.2	3.95	3.25	6.50	3.95	53429
	TOP	3.1	3.0	213	63	48	63.2	7.49	46.48	8.15	78.81	78808
DEN 7	MIDDLE	3.1	2.9	193	28	37	143.2	10.44	10.44	8.63	32.92	55207
	BOTTOM	3.4	3.3	435	45	40	167.5	11.04	0.50	8.03	5.02	30119
	TOP	3.9	3.1	1011	215	186	260.6	4.72	35.64	26.96	57.12	106627
DOW 1	MIDDLE	4.2	3.5	2303	632	217	308.5	1.58	13.55	3.16	33.88	85835
	BOTTOM	4.2	3.6	4741	1365	384	953.4	1.71	12.25	2.28	37.90	113982
	TOP	3.5	3.3	277	43	106	276.3	26.45	28.84	85.79	53.38	65536
DOW 2	MIDDLE	3.8	3.5	463	89	54	387.7	5.04	4.74	16.51	15.28	47376
	BOTTOM	4.0	3.8	3437	890	152	289.2	4.51	6.48	9.02	18.31	109886
	TOP	3.1	3.0	302	63	76	81.2	0.51	40.73	0.51	78.24	107805
DOW 3	MIDDLE	3.2	2.9	121	42	73	177.0	1.28	39.60	0.00	53.17	100590
	BOTTOM	3.6	3.5	112	60	47	135.8	1.47	0.00	1.71	3.91	48909
	TOP	3.4	2.9	224	42	40	63.7	1.20	21.38	2.05	55.90	89443
DOW 4	MIDDLE	3.8	2.6	171	30	52	94.9	1.21	3.64	1.62	16.57	70723
	BOTTOM	3.8	2.9	154	21	67	209.1	1.46	0.00	0.00	11.28	65520

PLOT CODE	LAYERS	pH [H2O]	pH [CaCl2]	EXCH.Ca kg/ha	EXCH. Mg kg/ha	EXCH. K kg/ha	TOTAL P kg/ha	AV NO3-N kg/ha	AV NH4-N kg/ha	MI NO3-N kg/ha	MI NH4-N kg/ha	L.O.I kg/ha
	TOP	5.4	5.2	6217	371	208	933.3	71.05	9.71	204.76	0.00	127616
DOW 5	MIDDLE	5.3	4.8	3370	218	44	514.6	16.02	2.08	37.53	9.49	66750
	BOTTOM	7.3	6.8	15071	335	53	780.1	15.53	2.31	68.85	0.00	77666
	TOP	4.2	3.6	922	278	243	402.9	25.20	28.56	68.50	79.70	95188
DOW 6	MIDDLE	4.3	3.5	902	303	100	303.6	6.27	9.40	11.90	33.00	73096
	BOTTOM	4.6	3.8	5152	1497	226	341.4	2.60	7.79	3.57	33.42	113551
	TOP	4.4	4.9	2255	127	141	728.9	61.32	0.00	185.08	0.00	104692
DST 1	MIDDLE	4.6	4.8	1793	103	38	616.9	32.43	0.00	46.10	0.00	60555
	BOTTOM	4.6	4.7	1569	72	33	630.8	8.74	0.00	13.98	2.18	67728
	TOP	3.8	3.7	211	62	97	267.0	1.54	18.63	2.16	82.05	100836
GTN 1	MIDDLE	3.7	3.8	6	14	24	242.2	2.97	4.99	9.99	13.89	57750
	BOTTOM	3.8	4.1	0	10	24	284.7	1.00	2.20	6.79	1.80	42910
	TOP	3.4	3.2	292	105	122	111.2	0.08	2.06	0.63	31.98	122692
INV 1	MIDDLE	3.8	3.4	118	29	49	121.5	0.00	0.00	3.31	8.46	49653
	BOTTOM	4.3	3.9	150	22	39	166.3	0.32	0.00	3.51	4.15	43128
	TOP	3.7	3.6	210	72	64	101.2	0.21	13.25	0.77	30.13	61381
INV 2	MIDDLE	3.7	3.6	86	33	44	170.6	0.00	2.93	2.61	30.97	70091
	BOTTOM	3.7	3.9	16	23	59	338.0	0.00	0.00	5.91	19.03	123023
	TOP	3.5	3.1	95	81	110	121.9	0.74	54.16	4.59	96.43	98536
KCD 1	MIDDLE	3.4	3.3	0	22	43	178.9	6.89	16.20	2.23	50.26	56777
	BOTTOM	3.4	3.9	0	12	58	678.9	17.78	15.66	5.50	20.32	122761

PLOT CODE	LAYERS	pH [H2O]	pH [CaCl2]	EXCH.Ca kg/ha	EXCH. Mg kg/ha	EXCH. K kg/ha	TOTAL P kg/ha	AV NO3-N kg/ha	AV NH4-N kg/ha	MI NO3-N kg/ha	MI NH4-N kg/ha	L.O.I kg/ha
	TOP	3.1	2.8	75	90	73	141.2	10.85	49.59	5.13	95.95	131115
KCD 2	MIDDLE	3.3	3.1	0	24	38	145.9	2.44	12.66	5.78	47.09	74413
	BOTTOM	3.4	3.8	0	11	41	469.4	0.88	8.79	8.79	12.30	107629
	TOP	3.3	3.2	207	121	63	351.4	14.23	18.89	25.22	44.89	143587
KIN 1	MIDDLE	3.8	3.8	238	35	28	289.3	8.52	0.87	22.96	5.34	102546
	BOTTOM	4.1	4.0	306	53	31	527.1	1.66	0.00	6.65	7.36	97329
	TOP	3.3	3.1	96	112	61	246.6	1.35	10.52	4.70	31.15	135443
KIN 2	MIDDLE	3.6	3.5	27	30	23	351.4	2.55	2.93	7.66	15.06	105903
	BOTTOM	3.8	3.8	29	26	35	1561.8	0.00	0.00	5.26	6.25	138173
	TOP	3.4	3.6	246	63	77	837.1	19.60	20.12	62.49	56.14	112540
LAK 1	MIDDLE	3.4	3.7	91	18	32	850.9	13.87	3.68	25.47	16.70	73573
	BOTTOM	3.6	3.9	132	24	53	1721.4	10.18	8.98	22.76	13.18	134763
	TOP	3.0	3.5	171	37	75	400.2	35.69	14.69	183.76	49.70	97346
LAK 2	MIDDLE	3.4	3.9	28	6	28	332.5	9.25	1.24	43.47	0.69	53124
	BOTTOM	3.6	4.1	35	6	31	515.1	6.67	0.23	20.48	0.23	70178
	TOP	3.5	3.3	128	41	50	435.3	7.77	0.00	28.77	4.60	71662
LAK 3	MIDDLE	3.6	3.6	48	19	38	578.1	5.30	0.00	14.01	3.13	65282
	BOTTOM	3.7	3.9	33	9	29	728.8	5.38	0.74	7.98	3.34	74200
	TOP	3.7	3.3	172	118	38	135.6	1.31	18.50	1.64	40.10	105571
LCH 1	MIDDLE	3.7	3.8	26	21	17	185.6	6.77	7.47	9.34	27.09	77079
	BOTTOM	3.8	4.0	16	25	33	387.3	9.64	2.14	12.85	21.41	182005

PLOT CODE	LAYERS	pH [H2O]	pH [CaCl2]	EXCH.Ca	EXCH. Mg	EXCH. K	TOTAL P	AV NO3-N	AV NH4-N	MI NO3-N	MI NH4-N	L.O.I
				kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
	TOP	4.6	5.6	3211	110	61	166.5	0.00	11.76	5.57	31.75	56423
LND 1	MIDDLE	5.4	6.6	16345	225	71	783.6	0.00	2.29	13.14	0.00	25709
	BOTTOM	5.7	6.9	19683	274	88	724.8	0.00	0.00	0.00	0.00	16815
	TOP	5.3	5.6	2788	181	73	340.6	6.38	5.68	56.10	0.00	109713
LND 2	MIDDLE	5.5	6.7	14922	207	85	545.7	5.77	0.00	14.16	0.00	20983
	BOTTOM	5.7	7.1	18992	258	96	809.5	4.28	0.00	11.86	0.00	32932
	TOP	3.7	3.4	862	154	97	610.1	11.12	29.60	34.56	66.56	136719
LOT 1	MIDDLE	4.4	4.1	2019	292	58	635.3	5.57	18.96	7.83	54.10	86978
	BOTTOM	4.8	4.5	2761	456	50	766.0	2.83	1.96	2.61	23.27	87006
	TOP	3.1	3.0	145	60	93	404.2	19.05	11.06	36.13	42.55	101691
LOT 2	MIDDLE	3.5	3.5	17	12	56	393.1	4.44	4.44	8.66	20.75	67692
	BOTTOM	3.7	3.7	9	7	29	491.7	2.36	0.79	4.99	7.74	61683
	TOP	3.2	2.9	105	64	40	54.8	0.63	31.64	1.77	53.66	83034
LWT 1	MIDDLE	3.0	2.8	20	22	16	81.6	3.19	5.45	6.92	17.99	69626
	BOTTOM	n/a	n/a	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	TOP	3.1	3.3	36	41	50	643.0	15.62	15.62	42.18	38.12	147570
LWT 2	MIDDLE	3.5	3.9	5	4	18	802.0	12.49	0.00	16.90	1.47	98467
	BOTTOM	3.7	4.1	4	2	13	652.9	2.34	0.00	5.71	0.00	60970
	TOP	3.7	3.8	458	83	186	202.3	56.55	13.42	63.15	127.62	72612
MCH 1	MIDDLE	3.9	3.7	159	46	81	161.9	13.70	7.21	9.61	56.49	46872
	BOTTOM	4.3	4.0	327	168	88	152.9	0.00	6.35	3.29	21.16	39967

PLOT CODE	LAYERS	pH [H2O]	pH [CaCl2]	EXCH.Ca kg/ha	EXCH. Mg kg/ha	EXCH. K kg/ha	TOTAL P kg/ha	AV NO3-N kg/ha	AV NH4-N kg/ha	MI NO3-N kg/ha	MI NH4-N kg/ha	L.O.I kg/ha
	TOP	4.5	4.7	4924	434	278	761.5	95.77	39.38	135.14	209.52	162851
MCH 2	MIDDLE	5.5	5.1	5101	376	116	724.9	31.00	31.91	21.88	84.79	100289
	BOTTOM	5.5	5.2	6541	541	150	1014.9	9.70	17.90	10.44	69.36	134253
	TOP	3.2	3.1	764	78	150	255.5	29.21	44.33	20.75	164.24	196006
MID 1	MIDDLE	3.5	3.4	275	25	49	141.8	7.94	8.51	3.40	39.44	42560
	BOTTOM	3.6	3.7	165	16	29	162.5	6.86	0.69	3.43	17.83	42857
	TOP	3.6	3.2	152	60	67	137.3	0.00	15.78	3.57	55.70	71344
MOR 1	MIDDLE	3.5	3.4	18	21	28	167.3	4.98	0.00	7.07	28.03	64181
	BOTTOM	3.6	3.7	28	23	28	340.0	12.38	0.00	8.26	21.55	100895
	TOP	3.2	2.8	152	66	57	53.9	2.31	0.00	2.38	22.53	74733
MOR 2	MIDDLE	3.5	3.4	48	11	20	51.0	2.42	0.00	4.15	9.67	13821
	BOTTOM	3.6	4.1	117	19	36	225.3	5.86	0.00	5.86	21.50	9774
	TOP	3.4	2.8	42	55	81	134.1	2.00	0.00	0.00	36.20	169876
MOR 3	MIDDLE	3.5	2.9	7	19	30	112.3	4.17	0.00	0.18	7.44	105236
	BOTTOM	3.8	3.6	0	9	18	123.7	13.57	0.00	1.55	13.57	54263
	TOP	3.8	3.2	221	39	61	40.9	0.21	26.37	0.24	46.23	62156
NEW 1	MIDDLE	3.6	3.2	1021	77	226	200.6	1.34	11.81	0.00	35.19	115827
	BOTTOM	3.7	3.5	2132	196	626	291.5	3.41	6.81	0.00	22.56	144730
	TOP	3.4	3.7	724	69	111	536.9	40.51	24.13	41.70	132.26	98305
NTH 1	MIDDLE	4.1	4.1	1672	91	53	782.1	39.78	21.50	26.34	108.59	102138
	BOTTOM	5.1	5.4	4211	216	40	955.9	28.52	5.31	19.89	47.08	92840

PLOT CODE	LAYERS	pH [H2O]	pH [CaCl2]	EXCH.Ca kg/ha	EXCH. Mg kg/ha	EXCH. K kg/ha	TOTAL P kg/ha	AV NO3-N kg/ha	AV NH4-N kg/ha	MI NO3-N kg/ha	MI NH4-N kg/ha	L.O.I kg/ha
	TOP	4.7	5.0	8433	326	668	1339.6	214.11	2.96	160.90	131.76	240711
NTH 2	MIDDLE	6.4	6.1	16951	337	349	1073.6	37.57	0.98	69.29	24.40	124424
	BOTTOM	7.2	6.9	15606	520	311	854.9	22.54	1.37	26.64	23.90	71715
	TOP	3.2	3.6	1913	155	185	699.5	43.23	0.54	42.15	29.18	118894
NYM 1	MIDDLE	4.6	4.6	4123	224	99	597.4	17.39	0.00	23.53	0.51	63945
	BOTTOM	6.7	6.5	7224	197	65	384.0	16.33	0.00	18.14	2.72	40814
	TOP	3.4	2.9	215	137	62	98.0	0.00	1.72	0.54	18.66	160288
SEA 1	MIDDLE	3.5	3.5	19	20	34	152.5	0.00	0.00	1.25	18.79	109593
	BOTTOM	3.6	4.1	24	9	35	524.1	1.83	0.00	3.66	1.22	115827
	TOP	3.3	2.8	116	67	61	227.0	2.46	42.55	2.70	72.69	123401
SEW 1	MIDDLE	3.2	3.0	15	17	35	308.9	2.98	6.53	3.78	14.44	66471
	BOTTOM	3.6	3.6	4	5	32	521.4	4.54	1.78	8.11	3.57	85924
	TOP	3.3	3.3	411	157	193	578.6	36.52	18.05	70.09	34.42	172089
SFD 1	MIDDLE	3.5	3.5	83	68	89	393.9	11.65	4.13	8.26	9.02	75132
	BOTTOM	3.8	3.7	521	168	156	515.8	16.27	4.88	14.10	11.39	97603
	TOP	3.9	3.5	156	96	99	195.2	0.83	24.59	3.13	90.04	127142
SNT 1	MIDDLE	3.8	3.9	71	65	36	333.4	3.34	21.90	20.78	47.14	194853
	BOTTOM	3.9	4.0	54	51	29	382.6	0.42	6.64	4.57	44.85	114206
	TOP	5.9	6.2	4518	1121	607	765.4	116.46	0.83	212.20	73.77	130554
SWD 1	MIDDLE	6.3	6.5	2348	796	125	425.7	34.34	1.56	31.53	56.19	59312
	BOTTOM	7.0	6.8	2773	1596	129	528.3	40.17	0.00	52.83	50.21	91695

PLOT CODE	LAYERS	pH [H2O]	pH [CaCl2]	EXCH.Ca kg/ha	EXCH. Mg kg/ha	EXCH. K kg/ha	TOTAL P kg/ha	AV NO3-N kg/ha	AV NH4-N kg/ha	MI NO3-N kg/ha	MI NH4-N kg/ha	L.O.I kg/ha
	TOP	3.1	3.1	280	56	80	658.0	7.65	12.32	6.37	32.28	95566
SWD 2	MIDDLE	3.3	3.7	0	13	36	464.5	2.64	0.00	3.77	0.38	37684
	BOTTOM	3.3	3.9	0	11	37	576.9	5.55	0.00	2.77	0.46	41601
	TOP	3.0	3.0	368	57	77	269.9	11.65	30.45	7.52	64.67	118429
SWD 3	MIDDLE	3.1	3.4	0	12	40	206.9	4.73	0.00	5.16	12.04	27955
	BOTTOM	3.4	3.8	0	13	50	342.9	5.74	0.00	7.66	3.83	35102
	TOP	3.3	3.6	332	67	80	783.7	36.40	3.66	114.57	17.34	119698
SWP 1	MIDDLE	3.8	4.0	161	22	49	836.1	11.43	3.03	23.20	4.03	85740
	BOTTOM	4.5	4.5	273	52	56	890.9	10.10	3.37	7.48	8.98	67361
	TOP	3.7	3.2	249	90	118	174.2	0.67	55.90	1.35	114.15	108592
SWP 2	MIDDLE	3.8	3.6	74	21	76	264.6	11.60	20.16	1.90	52.50	52311
	BOTTOM	3.8	4.0	83	22	124	596.5	11.95	17.01	5.06	41.83	98820
	TOP	3.3	3.1	324	65	186	495.2	27.13	110.19	44.89	159.16	129633
SWP 3	MIDDLE	3.5	3.7	63	6	50	305.8	11.92	12.09	8.78	32.79	26493
	BOTTOM	4.0	4.0	79	8	45	291.6	7.92	7.92	4.71	14.12	29956
	TOP	3.8	3.6	89	54	55	377.3	13.82	12.05	42.60	38.42	50085
TAY 1	MIDDLE	3.7	3.9	2	23	19	479.4	14.98	0.50	26.25	14.98	42907
	BOTTOM	4.1	4.1	0	37	23	1227.2	17.68	0.00	20.15	14.80	74013
	TOP	5.1	5.0	3582	405	339	890.8	72.41	0.00	182.01	2.80	86673
TAY 2	MIDDLE	5.3	5.2	4093	484	161	1121.4	36.84	0.00	71.82	3.72	72561
	BOTTOM	5.6	5.3	6215	821	128	1627.6	32.31	1.10	39.43	5.48	79405

PLOT CODE	LAYERS	pH [H2O]	pH [CaCl2]	EXCH.Ca kg/ha	EXCH. Mg kg/ha	EXCH. K kg/ha	TOTAL P kg/ha	AV NO3-N kg/ha	AV NH4-N kg/ha	MI NO3-N kg/ha	MI NH4-N kg/ha	L.O.I kg/ha
	TOP	3.7	3.0	428	26	37	269.3	13.23	18.11	30.42	25.44	74270
THT 1	MIDDLE	4.5	3.9	1894	42	71	839.3	26.90	25.42	64.84	38.69	81056
	BOTTOM	5.8	5.7	1886	37	30	373.6	4.91	0.00	11.51	1.13	26419
	TOP	3.3	2.9	436	35	59	96.5	0.24	26.12	0.42	44.64	127149
THT 2	MIDDLE	3.1	2.8	219	24	50	398.7	4.38	0.00	1.46	9.04	58343
	BOTTOM	3.7	3.4	177	13	38	1606.0	5.13	0.00	2.24	11.22	80174
	TOP	4.6	4.6	5495	242	168	1175.7	92.52	0.00	188.74	2.36	90837
THT 3	MIDDLE	6.5	6.4	12608	219	96	1237.8	33.93	0.00	76.83	2.73	81895
	BOTTOM	7.1	6.8	1872	22	9	116.2	2.78	0.00	6.09	0.00	8097
	TOP	3.3	3.0	264	38	26	79.8	6.77	61.34	10.16	38.83	74655
THT 4	MIDDLE	3.6	3.0	59	18	49	350.4	5.61	23.98	9.35	31.81	34018
	BOTTOM	3.7	3.5	44	23	61	844.5	4.71	0.00	6.68	3.93	39286
	TOP	3.1	2.8	330	40	23	67.9	9.82	63.55	11.47	40.87	80738
THT 5	MIDDLE	3.4	3.0	96	19	35	286.8	6.01	7.75	6.20	14.35	31019
	BOTTOM	3.6	3.4	0	25	70	669.7	7.04	17.38	6.11	17.85	42267
	TOP	3.3	2.9	248	32	52	106.1	11.94	110.91	20.71	71.33	60823
THT 6	MIDDLE	3.3	2.8	190	32	86	856.4	16.81	16.81	40.58	6.96	78271
	BOTTOM	3.4	3.1	94	19	57	1070.9	10.29	7.80	15.91	10.29	46782
	TOP	3.2	2.9	321	52	53	53.3	0.14	20.82	0.00	45.75	82105
WLD 1	MIDDLE	3.3	2.7	1174	50	92	207.5	2.69	12.79	0.00	43.74	248989
	BOTTOM	3.5	3.2	1331	14	124	98.5	3.46	0.00	0.00	3.15	88181

PLOT CODE	LAYERS	OD EXCH. Ca mg/ 100g	OD EXCH. Mg mg/ 100g	OD EXCH. K mg/ 100g	OD TOTAL P mg/100g	OD AV. NO3 mg/ 100g	OD AV. NH4 mg/ 100g	OD MI. NO3 mg/ 100g	OD MI. NH4 mg/ 100g	OD L.O.I. kg/kg
	TOP	48.88	11.13	3.93	39.40	0.07	0.47	0.05	5.91	0.074
ABF 1	MIDDLE	51.61	4.08	0.39	32.20	0.12	0.00	0.10	0.33	0.004
	BOTTOM	67.24	3.40	0.6	34.00	0.23	0.00	0.00	0.12	0.004
	TOP	13.83	15.70	7	38.70	0.85	2.41	0.00	11.46	0.205
ABF 2	MIDDLE	1.77	0.95	0.92	36.30	1.03	0.67	0.04	3.32	0.078
	BOTTOM	0.66	0.46	0.53	41.70	0.96	0.00	0.07	1.55	0.076
	TOP	12.26	5.07	6.43	48.30	2.17	1.14	3.73	4.99	0.081
AE 1	MIDDLE	4.46	1.83	1.91	35.40	0.30	0.15	0.69	1.41	0.038
	BOTTOM	5.50	2.32	1.58	34.00	0.07	0.12	0.38	1.2	0.028
	TOP	77.17	10.04	6.94	59.90	1.40	1.61	0.57	8.07	0.191
AE 2	MIDDLE	55.69	4.99	3.32	52.80	0.69	0.12	1.33	0.52	0.118
	BOTTOM	37.38	3.61	2.26	46.10	0.05	0.00	0.56	0.48	0.056
	TOP	27.91	41.77	22.09	105.00	0.00	6.83	0.00	25.39	0.732
AWE 1	MIDDLE	11.46	17.92	2.34	64.40	0.38	7.51	2.79	24.66	0.461
	BOTTOM	2.14	1.75	2.02	31.00	0.09	0.47	0.23	2.54	0.084
	TOP	32.61	11.32	10.48	24.40	0.00	1.19	0.17	5.61	0.140
BAL 1	MIDDLE	5.38	2.90	2.69	19.10	0.33	0.14	0.49	1.29	0.054
	BOTTOM	4.37	2.74	2.35	15.70	0.18	0.00	0.44	0.39	0.035
	TOP	62.59	17.07	13.01	75.70	3.09	0.11	3.45	4.69	0.087
BCH 1	MIDDLE	21.96	17.64	6.44	73.30	1.28	0.00	0.94	1.28	0.040
	BOTTOM	23.29	23.85	5.69	74.40	2.08	0.00	2.16	0.71	0.033

PLOT CODE	LAYERS	OD EXCH. Ca mg/ 100g	OD EXCH. Mg mg/ 100g	OD EXCH. K mg/ 100g	OD TOTAL P mg/100g	OD AV. NO3 mg/ 100g	OD AV. NH4 mg/ 100g	OD MI. NO3 mg/ 100g	OD MI. NH4 mg/ 100g	OD L.O.I. kg/kg
	TOP	42.84	18.66	20.16	42.30	3.10	9.85	6.99	17.76	0.205
BCH 2	MIDDLE	0.00	1.99	4.61	30.20	1.34	0.10	4.08	0.86	0.096
	BOTTOM	0.00	0.92	3.26	35.20	0.82	0.00	1.40	0.19	0.066
	TOP	20.71	10.08	16.15	82.20	3.08	8.26	8.44	20.82	0.261
CER 1	MIDDLE	0.32	0.54	2.95	57.30	0.51	0.08	1.14	1.06	0.135
	BOTTOM	0.00	0.12	1.60	44.40	0.16	0.00	0.65	0.00	0.086
	TOP	117.84	7.24	17.81	31.50	7.99	1.43	19.34	0.65	0.109
CHT 1	MIDDLE	100.23	6.66	7.1	30.40	0.88	0.47	1.11	1.17	0.021
	BOTTOM	984.80	10.10	2.9	38.50	0.16	0.29	0.47	1.22	0.039
	TOP	23.03	5.76	11.54	37.60	3.10	1.04	8.77	2.28	0.070
DEN 1	MIDDLE	3.73	1.30	5.71	26.70	0.65	0.00	1.75	0.43	0.038
	BOTTOM	4.33	1.50	3.82	21.00	0.36	0.00	0.91	0.00	0.023
	TOP	43.91	9.47	12.05	38.20	3.16	3.05	3.52	10.80	0.184
DEN 2	MIDDLE	1.98	1.01	4.44	26.50	0.55	0.23	0.99	0.71	0.061
	BOTTOM	0.90	0.40	3.03	26.50	0.36	0.20	0.69	0.00	0.033
	TOP	11.99	3.85	11.57	31.90	2.96	2.78	6.06	5.14	0.062
DEN 3	MIDDLE	2.41	0.94	5.65	17.80	0.83	0.46	1.09	0.91	0.034
	BOTTOM	1.51	0.55	3.44	17.80	0.30	0.16	0.35	0.08	0.019
	TOP	32.11	9.39	12.43	23.30	1.61	1.73	3.95	3.31	0.057
DEN 4	MIDDLE	17.45	7.72	5.71	17.50	0.33	0.34	0.67	0.48	0.029
	BOTTOM	19.02	11.19	6.31	15.70	0.15	0.35	0.17	0.53	0.020

PLOT CODE	LAYERS	OD EXCH. Ca mg/ 100g	OD EXCH. Mg mg/ 100g	OD EXCH. K mg/ 100g	OD TOTAL P mg/100g	OD AV. NO3 mg/ 100g	OD AV. NH4 mg/ 100g	OD MI. NO3 mg/ 100g	OD MI. NH4 mg/ 100g	OD L.O.I. kg/kg
	TOP	16.49	6.44	9.31	16.40	0.07	2.52	0.00	5.27	0.053
DEN 5	MIDDLE	2.19	7.71	5.84	9.66	0.00	0.46	0.00	0.74	0.034
	BOTTOM	6.74	21.08	7.48	9.00	0.00	0.35	0.00	0.46	0.034
	TOP	16.20	6.96	7.41	26.00	2.16	0.79	5.89	1.87	0.079
DEN 6	MIDDLE	0.87	1.16	3.72	17.20	0.47	0.27	0.97	0.57	0.045
	BOTTOM	0.27	1.18	3.55	9.46	0.19	0.16	0.31	0.19	0.026
	TOP	180.15	53.24	40.66	53.50	6.34	39.33	6.89	66.68	0.667
DEN 7	MIDDLE	26.37	3.87	5.08	19.60	1.43	1.43	1.18	4.51	0.076
	BOTTOM	32.47	3.32	3.02	12.50	0.82	0.04	0.60	0.37	0.022
	TOP	80.30	17.11	14.73	20.70	0.38	2.83	2.14	4.54	0.085
DOW 1	MIDDLE	123.17	33.83	11.60	16.50	0.08	0.72	0.17	1.81	0.046
	BOTTOM	202.40	58.29	16.37	40.70	0.07	0.52	0.10	1.62	0.049
	TOP	28.29	4.43	10.85	28.20	2.70	2.94	8.76	5.45	0.067
DOW 2	MIDDLE	35.45	6.84	4.12	29.70	0.39	0.36	1.26	1.17	0.036
	BOTTOM	147.39	38.15	6.50	12.40	0.19	0.28	0.39	0.79	0.047
	TOP	191.27	40.08	48.11	51.50	0.32	25.84	0.32	49.63	0.684
DOW 3	MIDDLE	9.33	3.19	5.60	13.60	0.10	3.04	0.00	4.09	0.077
	BOTTOM	5.20	2.79	2.20	6.30	0.07	0.00	0.08	0.18	0.023
	TOP	152.04	28.80	27.32	43.20	0.81	14.51	1.39	37.94	0.607
DOW 4	MIDDLE	9.12	1.59	2.76	5.06	0.06	0.19	0.09	0.88	0.038
	BOTTOM	4.52	0.62	1.96	6.13	0.04	0.00	0.00	0.33	0.019

PLOT CODE	LAYERS	OD EXCH. Ca mg/ 100g	OD EXCH. Mg mg/ 100g	OD EXCH. K mg/ 100g	OD TOTAL P mg/100g	OD AV. NO3 mg/ 100g	OD AV. NH4 mg/ 100g	OD MI. NO3 mg/ 100g	OD MI. NH4 mg/ 100g	OD L.O.I. kg/kg
	TOP	391.01	23.31	13.08	58.70	4.47	0.61	12.88	0.00	0.080
DOW 5	MIDDLE	265.23	17.14	3.46	40.50	1.26	0.16	2.95	0.75	0.053
	BOTTOM	834.60	18.55	2.95	43.20	0.86	0.13	3.81	0.00	0.043
	TOP	60.18	18.18	15.86	26.30	1.64	1.86	4.47	5.20	0.062
DOW 6	MIDDLE	50.82	17.06	5.62	17.10	0.35	0.53	0.67	1.86	0.041
	BOTTOM	188.62	54.80	8.29	12.50	0.10	0.29	0.13	1.22	0.042
	TOP	160.55	9.08	10.06	51.90	4.37	0.00	13.18	0	0.075
DST 1	MIDDLE	118.31	6.80	2.53	40.70	2.14	0.00	3.04	0	0.040
	BOTTOM	89.27	4.10	1.86	35.90	0.50	0.00	0.80	0.12	0.039
	TOP	37.75	11.02	17.36	47.80	0.28	3.33	0.39	14.69	0.180
GTN 1	MIDDLE	1.02	2.35	3.88	39.60	0.48	0.82	1.63	2.27	0.094
	BOTTOM	0.00	1.13	2.83	33.60	0.12	0.26	0.80	0.21	0.051
	TOP	105.81	37.88	44.33	40.30	0.03	0.75	0.23	11.58	0.444
INV 1	MIDDLE	6.78	1.70	2.82	7.00	0.00	0.00	0.19	0.49	0.029
	BOTTOM	10.11	1.46	2.62	11.20	0.02	0.00	0.24	0.28	0.029
	TOP	77.78	26.54	23.88	37.50	0.08	4.91	0.28	11.16	0.227
INV 2	MIDDLE	12.51	4.82	6.4	24.70	0.00	0.42	0.38	4.48	0.101
	BOTTOM	1.24	1.71	4.48	25.50	0.00	0.00	0.45	1.44	0.093
	TOP	23.57	20.05	27.18	30.10	0.18	13.38	1.13	23.81	0.243
KCD 1	MIDDLE	0.00	3.22	6.24	26.20	1.01	2.37	0.33	7.36	0.083
	BOTTOM	0.00	0.80	3.73	44.00	1.15	1.02	0.36	1.32	0.080

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	TOP	26.48	31.90	25.8	49.80	3.82	17.48	1.81	33.83	0.462
KCD 2	MIDDLE	0.00	3.01	4.74	18.30	0.31	1.59	0.72	5.91	0.093
	BOTTOM	0.00	0.67	2.59	29.70	0.06	0.56	0.56	0.78	0.068
	TOP	31.39	18.36	9.59	53.30	2.16	2.86	3.83	6.81	0.218
KIN 1	MIDDLE	26.36	3.86	3.09	32.10	0.95	0.10	2.55	0.59	0.114
	BOTTOM	18.95	3.28	1.93	32.70	0.10	0.00	0.41	0.46	0.060
	TOP	28.28	32.81	17.96	72.30	0.40	3.08	1.38	9.13	0.397
KIN 2	MIDDLE	3.49	3.82	2.94	45.30	0.33	0.38	0.99	1.94	0.137
	BOTTOM	1.31	1.18	1.56	70.00	0.00	0.00	0.24	0.28	0.062
	TOP	28.39	7.30	8.88	96.50	2.26	2.32	7.20	6.47	0.130
LAK 1	MIDDLE	9.01	1.77	3.21	84.70	1.38	0.37	2.54	1.66	0.073
	BOTTOM	6.00	1.09	2.43	78.40	0.46	0.41	1.04	0.6	0.061
	TOP	34.73	7.43	15.35	81.40	7.26	2.99	37.37	10.11	0.198
LAK 2	MIDDLE	6.20	1.30	6.26	74.70	2.08	0.28	9.76	0.15	0.119
	BOTTOM	4.35	0.75	3.94	64.90	0.84	0.03	2.58	0.03	0.088
	TOP	34.70	11.00	13.43	118.00	2.11	0.00	7.80	1.25	0.194
LAK 3	MIDDLE	9.55	3.77	7.7	116.00	1.06	0.00	2.81	0.63	0.131
	BOTTOM	5.31	1.39	4.67	116.00	0.86	0.12	1.27	0.53	0.118
	TOP	50.33	34.42	11.07	39.70	0.38	5.42	0.48	11.74	0.309
LCH 1	MIDDLE	3.63	2.90	2.37	26.20	0.96	1.06	1.32	3.82	0.109
	BOTTOM	1.13	1.73	2.33	27.20	0.68	0.15	0.90	1.5	0.128

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	TOP	507.39	17.43	9.59	26.30	0.00	1.86	0.88	5.02	0.089
LND 1	MIDDLE	577.81	7.97	2.49	27.70	0.00	0.08	0.46	0.00	0.009
	BOTTOM	589.26	8.22	2.63	21.70	0.00	0.00	0.00	0.00	0.005
	TOP	399.47	25.98	10.49	48.80	0.91	0.81	8.04	0.00	0.157
LND 2	MIDDLE	577.01	8.01	3.30	21.10	0.22	0.00	0.55	0.00	0.008
	BOTTOM	586.55	7.96	2.97	25.00	0.13	0.00	0.37	0.00	0.010
	TOP	83.82	15.01	9.42	59.30	1.08	2.88	3.36	6.47	0.133
LOT 1	MIDDLE	152.85	22.10	4.40	48.10	0.42	1.44	0.59	4.10	0.066
	BOTTOM	158.97	26.23	2.89	44.10	0.16	0.11	0.15	1.34	0.050
	TOP	23.77	9.77	15.29	66.10	3.12	1.81	5.91	6.96	0.166
LOT 2	MIDDLE	2.30	1.69	7.70	54.00	0.61	0.61	1.19	2.85	0.093
	BOTTOM	0.90	0.75	3.08	52.00	0.25	0.08	0.53	0.82	0.065
	TOP	94.58	57.23	35.76	49.10	0.57	28.37	1.59	48.10	0.744
LWT 1	MIDDLE	6.63	7.34	5.18	26.80	1.05	1.79	2.27	5.91	0.229
	BOTTOM	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	TOP	4.46	5.15	6.21	80.20	1.95	1.95	5.26	4.75	0.184
LWT 2	MIDDLE	0.47	0.41	1.71	77.90	1.21	0.00	1.64	0.14	0.096
	BOTTOM	0.41	0.19	1.26	65.20	0.23	0.00	0.57	0.00	0.061
	TOP	57.25	10.43	23.23	25.30	7.07	1.68	7.90	15.96	0.091
MCH 1	MIDDLE	16.07	4.63	8.18	16.40	1.39	0.73	0.97	5.72	0.047
	BOTTOM	32.69	16.79	8.77	15.30	0.00	0.64	0.33	2.12	0.040

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	TOP	302.00	26.59	17.05	46.70	5.87	2.41	8.29	12.85	0.100
MCH 2	MIDDLE	294.84	21.74	6.72	41.90	1.79	1.84	1.26	4.9	0.058
	BOTTOM	219.78	18.19	5.04	34.10	0.33	0.60	0.35	2.33	0.045
	TOP	101.31	10.30	19.89	33.90	3.88	5.88	2.75	21.79	0.260
MID 1	MIDDLE	23.87	2.14	4.28	12.30	0.69	0.74	0.30	3.42	0.037
	BOTTOM	11.34	1.11	1.98	11.20	0.47	0.05	0.24	1.23	0.030
	TOP	25.74	10.11	11.27	23.20	0.00	2.67	0.60	9.41	0.121
MOR 1	MIDDLE	1.55	1.79	2.32	14.10	0.42	0.00	0.60	2.36	0.054
	BOTTOM	1.34	1.11	1.34	16.50	0.60	0.00	0.40	1.05	0.049
	TOP	61.86	26.85	22.98	21.90	0.94	0.00	0.97	9.15	0.303
MOR 2	MIDDLE	2.84	0.67	1.16	2.99	0.14	0.00	0.24	0.57	0.008
	BOTTOM	2.43	0.38	0.75	4.66	0.12	0.00	0.12	0.44	0.002
	TOP	4.97	6.49	9.5	15.80	0.24	0.00	0.00	4.27	0.200
MOR 3	MIDDLE	1.02	2.65	4.26	15.80	0.59	0.00	0.03	1.05	0.148
	BOTTOM	0.00	0.56	1.07	7.41	0.81	0.00	0.09	0.81	0.033
	TOP	191.75	33.87	52.97	35.50	0.18	22.87	0.21	40.10	0.539
NEW 1	MIDDLE	53.95	4.07	11.93	10.60	0.07	0.62	0.00	1.86	0.061
	BOTTOM	58.57	5.38	17.19	8.01	0.09	0.19	0.00	0.62	0.040
	TOP	60.81	5.78	9.31	45.10	3.40	2.03	3.50	11.11	0.083
NTH 1	MIDDLE	73.54	4.00	2.34	34.40	1.75	0.95	1.16	4.78	0.045
	BOTTOM	145.38	7.44	1.4	33.00	0.98	0.18	0.69	1.63	0.032

PLOT CODE	LAYERS	OD EXCH. Ca mg/ 100g	OD EXCH. Mg mg/ 100g	OD EXCH. K mg/ 100g	OD TOTAL P mg/100g	OD AV. NO3 mg/ 100g	OD AV. NH4 mg/ 100g	OD MI. NO3 mg/ 100g	OD MI. NH4 mg/ 100g	OD L.O.I. kg/kg
	TOP	595.54	23.05	47.18	94.60	15.12	0.21	11.36	9.3	0.170
NTH 2	MIDDLE	929.92	18.50	19.14	58.90	2.06	0.05	3.80	1.34	0.068
	BOTTOM	589.66	19.64	11.74	32.30	0.85	0.05	1.01	0.9	0.027
	TOP	97.09	7.87	9.38	35.50	2.19	0.03	2.14	1.48	0.060
NYM 1	MIDDLE	201.52	10.93	4.83	29.20	0.85	0.00	1.15	0.03	0.031
	BOTTOM	391.27	10.68	3.51	20.80	0.88	0.00	0.98	0.15	0.022
	TOP	72.24	46.21	20.82	33.00	0.00	0.58	0.18	6.28	0.540
SEA 1	MIDDLE	1.39	1.51	2.48	11.30	0.00	0.00	0.09	1.39	0.081
	BOTTOM	0.90	0.34	1.28	19.30	0.07	0.00	0.13	0.04	0.043
	TOP	25.87	14.94	13.56	50.70	0.55	9.50	0.60	16.23	0.276
SEW 1	MIDDLE	1.64	1.81	3.74	32.80	0.32	0.69	0.40	1.53	0.071
	BOTTOM	0.30	0.38	2.46	40.20	0.35	0.14	0.63	0.28	0.066
	TOP	24.74	9.44	11.59	34.80	2.20	1.09	4.22	2.07	0.104
SFD 1	MIDDLE	5.10	4.22	5.47	24.30	0.72	0.25	0.51	0.56	0.046
	BOTTOM	21.80	7.02	6.54	21.60	0.68	0.20	0.59	0.48	0.041
	TOP	42.05	25.85	26.57	52.50	0.22	6.62	0.84	24.22	0.342
SNT 1	MIDDLE	7.80	7.19	3.98	36.90	0.37	2.42	2.30	5.22	0.216
	BOTTOM	4.98	4.71	2.68	35.30	0.04	0.61	0.42	4.14	0.105
	TOP	320.51	79.51	43.05	54.30	8.26	0.06	15.06	5.23	0.093
SWD 1	MIDDLE	188.04	63.76	10.03	34.10	2.75	0.13	2.53	4.5	0.048
	BOTTOM	161.12	92.76	7.48	30.70	2.33	0.00	3.07	2.92	0.053

PLOT CODE	LAYERS	OD EXCH. Ca mg/ 100g	OD EXCH. Mg mg/ 100g	OD EXCH. K mg/ 100g	OD TOTAL P mg/100g	OD AV. NO3 mg/ 100g	OD AV. NH4 mg/ 100g	OD MI. NO3 mg/ 100g	OD MI. NH4 mg/ 100g	OD L.O.I. kg/kg
	TOP	14.53	2.88	4.16	34.10	0.40	0.64	0.33	1.67	0.050
SWD 2	MIDDLE	0.00	0.73	2.03	26.40	0.15	0.00	0.21	0.02	0.021
	BOTTOM	0.00	0.51	1.7	26.50	0.25	0.00	0.13	0.02	0.019
	TOP	22.66	3.49	4.74	16.60	0.72	1.87	0.46	3.98	0.073
SWD 3	MIDDLE	0.00	0.57	1.95	10.20	0.23	0.00	0.25	0.59	0.014
	BOTTOM	0.00	0.45	1.68	11.40	0.19	0.00	0.25	0.13	0.012
	TOP	40.74	8.18	9.82	96.10	4.46	0.45	14.05	2.13	0.147
SWP 1	MIDDLE	13.28	1.77	4.04	68.80	0.94	0.25	1.91	0.33	0.071
	BOTTOM	19.26	3.69	3.93	62.80	0.71	0.24	0.53	0.63	0.047
	TOP	59.07	21.43	27.98	41.30	0.16	13.25	0.32	27.06	0.257
SWP 2	MIDDLE	11.05	3.12	11.3	39.40	1.73	3.00	0.28	7.82	0.078
	BOTTOM	5.08	1.33	7.59	36.60	0.73	1.04	0.31	2.57	0.061
	TOP	43.59	8.78	25.02	66.60	3.65	14.82	6.04	21.41	0.174
SWP 3	MIDDLE	9.84	1.01	7.77	47.80	1.86	1.89	1.37	5.13	0.041
	BOTTOM	9.07	0.88	5.15	33.40	0.91	0.91	0.54	1.62	0.034
	TOP	17.17	10.48	10.7	73.00	2.67	2.33	8.24	7.43	0.097
TAY 1	MIDDLE	0.24	3.28	2.73	67.70	2.11	0.07	3.71	2.11	0.061
	BOTTOM	0.00	2.04	1.25	67.70	0.98	0.00	1.11	0.82	0.041
	TOP	330.90	37.38	31.36	82.30	6.69	0.00	16.82	0.26	0.080
TAY 2	MIDDLE	262.44	31.02	10.35	71.90	2.36	0.00	4.60	0.24	0.047
	BOTTOM	262.74	34.72	5.39	68.80	1.37	0.05	1.67	0.23	0.034

PLOT CODE	LAYERS	OD EXCH. Ca mg/ 100g	OD EXCH. Mg mg/ 100g	OD EXCH. K mg/ 100g	OD TOTAL P mg/100g	OD AV. NO3 mg/ 100g	OD AV. NH4 mg/ 100g	OD MI. NO3 mg/ 100g	OD MI. NH4 mg/ 100g	OD L.O.I. kg/kg
	TOP	47.18	2.87	4.11	29.70	1.46	2.00	3.36	2.81	0.082
THT 1	MIDDLE	54.38	1.21	2.05	24.10	0.77	0.73	1.86	1.11	0.023
	BOTTOM	104.52	2.03	1.65	20.70	0.27	0.00	0.64	0.06	0.015
	TOP	209.70	17.05	28.27	46.40	0.12	12.56	0.20	21.46	0.611
THT 2	MIDDLE	7.68	0.84	1.74	14.00	0.15	0.00	0.05	0.32	0.020
	BOTTOM	5.78	0.44	1.23	52.40	0.17	0.00	0.07	0.37	0.026
	TOP	184.60	8.12	5.63	39.50	3.11	0.00	6.34	0.08	0.031
THT 3	MIDDLE	349.37	6.07	2.66	34.30	0.94	0.00	2.13	0.08	0.023
	BOTTOM	544.66	6.26	2.62	33.80	0.81	0.00	1.77	0.00	0.024
	TOP	160.78	23.41	16.13	48.70	4.13	37.42	6.20	23.69	0.455
THT 4	MIDDLE	3.63	1.09	3.02	21.60	0.35	1.48	0.58	1.96	0.021
	BOTTOM	1.18	0.61	1.64	22.60	0.13	0.00	0.18	0.11	0.011
	TOP	172.25	21.08	12.03	35.40	5.12	33.13	5.98	21.30	0.421
THT 5	MIDDLE	5.23	1.05	1.88	15.60	0.33	0.42	0.34	0.78	0.017
	BOTTOM	0.00	0.56	1.53	14.70	0.15	0.38	0.13	0.39	0.009
	TOP	94.77	12.33	20.06	40.60	4.57	42.46	7.93	27.31	0.233
THT 6	MIDDLE	7.37	1.24	3.36	33.30	0.65	0.65	1.58	0.27	0.030
	BOTTOM	3.22	0.67	1.98	36.90	0.35	0.27	0.55	0.35	0.016
	TOP	291.01	47.33	47.74	48.30	0.12	18.89	0.00	41.50	0.745
WLD 1	MIDDLE	71.30	3.05	5.61	12.60	0.16	0.78	0.00	2.66	0.151
	BOTTOM	48.38	0.50	4.51	3.58	0.13	0.00	0.00	0.11	0.032

APPENDIX 5
STATISTICAL ANALYSIS RESULTS

De-trended Canonical Correspondence Analysis
Correlation coefficients between soil chemical variables and axes

	Axis 1	Axis 2	Axis 3	Axis 4
Species-environment correlation	**0.94**	**0.85**	**0.80**	**0.75**
Variation fraction explained	**0.21**	**0.11**	**0.09**	**0.05**
pH [H_2O][TOP LAYER]	**-0.59**	*-0.03*	*-0.13*	*0.24*
pH [H_2O][MIDDLE LAYER]	**-0.68**	*-0.16*	*-0.03*	*0.06*
pH [H_2O][BOTTOM LAYER]	**-0.65**	*-0.21*	*-0.04*	*-0.02*
pH [$CaCl_2$][TOP LAYER]	**-0.72**	*-0.13*	*-0.21*	*0.15*
pH [$CaCl_2$][MIDDLE LAYER]	**-0.64**	*-0.32*	*-0.10*	*0.07*
pH [$CaCl_2$][BOTTOM LAYER]	**-0.59**	*-0.31*	*-0.04*	*0.04*
EXCH. CALCIUM	**-0.73**	*0.08*	*-0.05*	*0.05*
EXCH. MAGNESIUM	**-0.63**	*0.14*	*-0.28*	*0.04*
EXCH. POTASSIUM	**-0.62**	*0.36*	*-0.10*	*-0.24*
TOTAL PHOSPHORUS	**-0.56**	*-0.42*	*0.23*	*0.04*
AV. NITRATE-NITROGEN	**-0.68**	*-0.15*	*0.17*	*-0.18*
MIN. NITRATE-NITROGEN	**-0.66**	*-0.31*	*0.15*	*-0.16*
AV. AMMONIUM-NITROGEN	*0.09*	*0.48*	*0.21*	*0.08*
MIN. AMMONIUM-NITROGEN	*0.16*	*0.39*	*-0.05*	*-0.28*
LOSS-ON-IGNITION	*-0.01*	*0.27*	*0.23*	*-0.06*

De-trended Canonical Correspondence Analysis
Site scores [from linear combination of chemical variables]

	Axis 1	Axis 2	Axis 3	Axis 4
ABF 1	26	-215	-19	40
ABF 2	92	-56	-28	119
AE 1	-6	-63	16	2
AE 2	12	-21	31	68
AWE 1	15	-48	32	-8
BAL 1	99	-20	-38	0
BCH 1	-12	-108	-188	14
BCH 2	73	-16	30	-42
CER 1	97	-51	74	-7
CHT 1	-40	-49	-88	-82
DEN 1	-33	-27	31	-60
DEN 2	61	12	56	-34
DEN 3	-57	9	0	-89
DEN 4	-87	37	-59	-31
DEN 5	0	95	-190	45
DEN 6	-31	-1	-23	-24
DEN 7	15	79	-50	22
DOW 1	-12	92	29	-26
DOW 2	-42	36	-29	3
DOW 3	50	118	-58	20
DOW 4	25	138	34	29
DOW 5	-178	29	44	144
DOW 6	-67	106	-24	1
DST 1	-131	-46	-10	106
GTN 1	77	12	-33	23
INV 1	118	13	-85	-94
INV 2	188	16	18	-27
KCD 1	70	55	48	43
KCD 2	89	19	46	13
KIN 1	92	-19	18	17
KIN 2	85	-95	16	25
LAK 1	-1	-49	51	19
LAK 2	-4	-70	36	-71
LAK 3	84	-109	41	22
LCH 1	92	-18	8	50

De-trended Canonical Correspondence Analysis
Site scores [from linear combination of chemical variables]

	Axis 1	Axis 2	Axis 3	Axis 4
LND 1	-49	-82	-197	94
LND 2	-110	-56	24	216
LOT 1	-28	-25	14	30
LOT 2	32	-51	38	-72
LWT 1	98	51	-116	47
LWT 2	29	-144	48	1
MCH 1	-66	73	-108	-74
MCH 2	-192	86	42	20
MID 1	28	110	42	-50
MOR 1	101	11	-14	14
MOR 2	158	-67	-105	-80
MOR 3	173	16	-44	-18
NEW 1	47	245	11	-18
NTH 1	-47	-1	19	12
NTH 2	-194	32	81	-150
NYM 1	-63	-120	-54	-155
SEA 1	230	-35	7	6
SEW 1	90	-1	47	21
SFD 1	-52	26	22	-57
SNT 1	106	17	11	-13
SWD 1	-169	-3	-196	-36
SWD 2	59	-71	3	26
SWD 3	54	0	-15	-30
SWP 1	-55	-93	32	-39
SWP 2	37	93	67	9
SWP 3	-12	23	48	-109
TAY 1	20	-146	-54	25
TAY 2	-150	-38	-27	51
THT 1	12	-21	204	-4
THT 2	65	27	50	57
THT 3	-176	-164	99	-44
THT 4	-24	20	72	71
THT 5	-17	12	55	44
THT 6	-37	36	126	35
WLD 1	73	232	55	27

De-trended Correspondence Analysis
Site scores

	Axis 1	Axis 2	Axis 3	Axis 4
ABF 1	-17	-17	-130	-55
ABF 2	75	26	91	-33
AE 1	-25	-4	-136	13
AE 2	-14	1	-181	-27
AWE 1	0	-17	-88	-33
BAL 1	228	-26	-2	4
BCH 1	-14	2	-194	-25
BCH 2	-3	-8	-31	9
CER 1	44	38	84	-6
CHT 1	-38	-6	-32	86
DEN 1	-42	-24	-19	21
DEN 2	-14	-34	40	-50
DEN 3	-37	-29	0	94
DEN 4	-43	-17	-11	65
DEN 5	-50	-19	116	-40
DEN 6	-28	-24	-38	71
DEN 7	-23	-30	-16	-46
DOW 1	-18	-47	44	-124
DOW 2	-44	-24	1	81
DOW 3	11	-63	85	-25
DOW 4	-11	-53	62	-160
DOW 5	-104	65	91	34
DOW 6	-47	-14	52	17
DST 1	-55	-22	72	161
GTN 1	6	-25	28	21
INV 1	293	-18	16	-15
INV 2	-2	13	-108	8
KCD 1	49	45	106	-7
KCD 2	40	35	63	-11
KIN 1	261	-40	11	24
KIN 2	12	-1	-78	-37
LAK 1	-24	11	-83	214
LAK 2	-35	-3	-95	176
LAK 3	-13	-5	-100	-14
LCH 1	16	23	-20	29

De-trended Correspondence Analysis
Site scores

	Axis 1	Axis 2	Axis 3	Axis 4
LND 1	-25	-21	-109	-46
LND 2	-37	-22	-42	4
LOT 1	-21	-15	-123	-50
LOT 2	-4	-20	-9	-50
LWT 1	5	-31	-5	-99
LWT 2	-13	-16	-99	-36
MCH 1	-28	-33	58	84
MCH 2	-104	53	258	-21
MID 1	-5	-37	53	-110
MOR 1	159	843	-3	4
MOR 2	383	-59	-35	6
MOR 3	383	-30	-2	-31
NEW 1	0	-51	80	-83
NTH 1	-43	-28	51	59
NTH 2	-101	78	-96	3
NYM 1	-47	4	-87	-31
SEA 1	370	-60	-41	8
SEW 1	52	31	90	-26
SFD 1	-38	-19	-43	31
SNT 1	114	-90	117	300
SWD 1	-83	29	133	90
SWD 2	-16	-5	-22	10
SWD 3	-15	-15	13	-24
SWP 1	-32	-20	-50	0
SWP 2	13	-36	61	-90
SWP 3	-14	-37	-7	-91
TAY 1	-22	-27	-36	56
TAY 2	-128	114	-62	-82
THT 1	-26	30	-93	244
THT 2	45	41	100	-19
THT 3	-121	109	-105	-140
THT 4	-27	-30	-37	-45
THT 5	-43	-32	-50	-81
THT 6	-15	-42	29	-62
WLD 1	-3	-58	68	-133

De-trended Canonical Correspondence Analysis
Species Scores

	Axis 1	Axis 2	Axis 3	Axis 4
ABIEGRAN	121	19	-28	34
ACERCAMP	-139	120	12	157
ACERPSEU	-131	3	-91	28
AGROCAPI	73	-58	24	-42
AGROSTOL	-31	-96	39	-48
AJUGREPT	-109	5	15	142
ALLIURSI	-203	-5	-389	-89
ANEMNEMO	-48	61	-122	-57
ANGESYLV	-224	90	-36	-46
ANISSTER	-234	54	161	-370
ANTHODOR	-19	43	-35	-59
ARCTMINU	-231	144	84	49
ARRHELAT	-109	-88	-51	-93
ARUMMACU	-212	78	-13	67
ATHYFILI	-40	-76	-10	-65
BETUPEND	64	164	-1	102
BETUPUBE	151	-22	-69	-83
BLECSPIC	48	-99	-24	32
BRACSYLV	-127	-18	-138	-59
BROMRAMO	-229	134	53	40
CALLVULG	180	-27	-91	-85
CARDFLEX	-76	-200	-107	-381
CAREAREN	-11	-197	-256	162
CAREBINE	160	-31	-42	17
CARELAEV	18	-81	64	-19
CAREREMO	-104	62	-117	-76
CARESYLV	-158	127	-75	-1
CARPBETU	-213	49	88	354
CASTSATI	-15	32	91	74
CENTNIGR	-1	-82	100	47
CERAFONT	194	24	16	-36
CERASEMI	78	46	99	141
CHAMANGU	-71	-109	-94	-21
CHAMLAWS	-1	-82	100	47
CHRYOPPO	-104	62	-117	-76
CIRCLUTE	-140	107	7	66
CIRSARVE	-210	42	169	-338
CIRSPALU	-60	-140	-34	-182
CONIMACU	-234	54	161	-370
CONOMAJU	-104	106	-220	-158
CORYAVEL	-90	117	-219	61
CORYCLAV	32	-68	27	-44
CRATMONO	-107	112	28	0
CYTISCOP	173	11	127	-53

De-trended Canonical Correspondence Analysis
Species Scores

	Axis 1	Axis 2	Axis 3	Axis 4
DACTGLOM	-52	-33	-7	-39
DESCCESP	-67	-3	-79	-32
DESCFLEX	94	-6	61	52
DIGIPURP	8	-76	-24	-9
DRYOAFFI	29	-99	10	3
DRYOCART	1	10	5	6
DRYODILA	14	-92	2	23
DRYOFILI	-67	-17	-19	143
EPILHIRS	-234	54	161	-370
EPILMONT	-2	91	20	-92
EQUISYLV	-132	-94	49	531
ERICCINE	125	19	-35	23
ERICTETR	111	-32	36	43
ERIOVAGI	111	-32	36	43
EUPHAMYG	-82	122	-172	-137
FAGUSYLV	-47	-18	-39	-36
FESTGIGA	-145	-148	25	-324
FESTOVIN	64	-214	-89	53
FESTRUBR	31	-360	-38	97
FILIULMA	-230	136	60	42
FRAGVESC	-96	101	-112	-22
FRANALNU	-231	144	84	49
FRAXEXCE	-205	102	56	134
GALETETR	-55	49	-43	-49
GALIAPAR	-205	-139	148	-82
GALIMOLL	-213	49	88	354
GALIODOR	-183	-14	-362	-104
GALISAXA	79	-11	162	21
GERAROBE	-57	-140	-19	-124
GEUMURBA	-216	-7	114	145
GLECHEDE	-167	77	49	66
GOODREPE	199	24	19	-42
GYMNDRYO	-14	-181	-372	35
HEDEHELI	-59	35	-7	115
HERASPHO	-211	10	-252	-159
HOLCLANA	14	-57	194	-21
HOLCMOLLI	10	-53	-21	-60
HYACNONS	-78	-11	-11	22
HYPEHIRS	-231	144	84	49
HYPEPULC	-41	-3	-7	-14
ILEXAQUI	-15	-14	-24	111
JUNCCONG	-37	-1	-45	-60
JUNCEFFU	-11	28	17	-54
JUNCSQUA	196	20	-72	-33

De-trended Canonical Correspondence Analysis
Species Scores

	Axis 1	Axis 2	Axis 3	Axis 4
LAMIALBU	-159	-71	-16	265
LAMIGALE	-175	-47	-168	121
LAPSCOMM	22	-206	109	13
LARIKAEM	12	-24	85	-223
LATHLINI	-79	122	-213	-183
LISTOVAT	-231	144	84	49
LONIPERI	-14	156	-48	-6
LOTUCORN	-59	-137	-389	232
LOTUULIG	-66	-156	63	-96
LUZUPILO	80	2	-41	-38
LUZUSYLV	64	-46	27	19
LYSINEMO	-48	15	-54	-59
MALUSYLV	-63	43	43	-140
MELAPRAT	0	93	-167	-63
MELIUNIF	-55	-35	-183	-198
MERCPERI	-202	41	-41	63
MILIEFFU	-63	43	43	-140
MOLICAER	102	118	-9	-6
MONTPERF	-7	-105	32	5
MYOSARVE	-234	54	161	-370
ORCHMASC	-231	144	84	49
OXALACET	29	-86	-43	27
PHALARUN	-234	54	161	-370
PICEABIE	-33	-42	27	73
PICESITC	113	-16	-35	107
PINUCONT	208	27	-88	-44
PINUSYLV	269	-50	11	11
PLANLANC	-59	-137	-389	232
POLYACUL	-231	144	84	49
POLYINTE	-59	-137	-389	232
POTEEREC	115	13	-18	-31
PRIMVERI	-213	49	88	354
PRIMVULG	-102	-4	55	3
PRUNAVIU	-79	122	-213	-183
PRUNVULG	-37	-1	-45	-60
PSEUMENZ	173	-43	44	-26
PTERAQUI	33	131	30	-24
QUERPETR	-1	-16	46	-117
QUERROBU	-6	-2	105	142
RANUFICA	-228	135	70	39
RANUREPE	-42	-103	-65	-78
ROSAARVE	-111	123	-93	-169
RUBUCAES	-86	-121	-225	344
RUBUFRUT	-35	-2	-11	-8

De-trended Canonical Correspondence Analysis
Species Scores

	Axis 1	Axis 2	Axis 3	Axis 4
RUBUIDAE	-39	-109	-23	-96
RUBUSAXA	92	19	-66	56
RUMEACET	52	-89	139	37
RUMEOBTU	-138	-40	-22	-175
RUMESANG	-225	51	150	-327
SAMBNIGR	-170	8	94	-316
SCRONODO	-186	52	36	246
SENESYLV	62	26	174	104
SILEDIOI	-102	-120	-49	-202
SOLADULC	-132	-94	49	531
SOLIVIRG	36	122	-264	70
SORBAUCU	84	36	-63	55
SORBTORM	0	158	-377	110
STACSYLV	-197	-69	-20	-128
STELGRAM	2	114	-70	17
STELHOLO	-45	-49	-27	-150
STELMEDI	7	-32	60	-1
STELNEMO	-14	-181	-372	35
SUCCPRAT	-79	122	-213	-183
TARAOFFI	-43	36	-169	-7
TEUCSCOR	-21	-5	-2	-104
THUJPLIC	121	19	-28	34
TRICCESP	208	27	-88	-44
TRIEEURO	98	-18	19	-126
TRISFLAV	-14	-181	-372	35
TSUGHETE	196	24	17	-38
ULEXEURO	121	19	-28	34
ULMUGLAB	-40	-45	61	-149
URTIDIOI	-186	-110	83	-15
VACCMYRT	106	2	-29	77
VACCULIG	127	29	21	-32
VACCVITI	276	-58	14	14
VALEOFFI	-231	144	84	49
VEROCHAM	-83	15	-99	65
VIBUOPUL	-66	-156	63	-96
VICIORUB	92	19	-66	56
VIOLPALU	114	-17	18	87
VIOLRIVI	29	31	-38	23

De-trended Correspondence Analysis
Species Scores

	Axis 1	Axis 2	Axis 3	Axis 4
ABIEGRAN	174	1005	-4	6
ACERCAMP	-79	25	95	37
ACERPSEU	-72	16	43	51
AGROCAPI	1	-7	-77	-3
AGROSTOL	-39	16	-124	120
AJUGREPT	-67	16	53	52
ALLIURSI	-91	34	182	137
ANEMNEMO	-29	-33	72	114
ANGESYLV	-107	59	240	20
ANISSTER	-110	93	-131	5
ANTHODOR	-21	-22	-4	72
ARCTMINU	-114	63	353	-32
ARRHELAT	-63	25	-108	15
ARUMMACU	-100	41	277	49
ATHYFILI	-32	-14	-97	-13
BETUPEND	-6	-43	20	-132
BETUPUBE	282	-40	-4	13
BLECSPIC	47	-18	-12	46
BRACSYLV	67	15	40	103
BROMRAMO	-112	61	342	-20
CALLVULG	357	-48	-8	4
CARDFLEX	-51	4	-119	-49
CAREAREN	18	-28	-144	-65
CAREBINE	302	-27	-1	-36
CARELAEV	0	-20	-121	-51
CAREREMO	-47	-20	-15	100
CARESYLV	-81	21	191	29
CARPBETU	-114	78	124	52
CASTSATI	-42	-38	-49	-121
CENTNIGR	-26	13	-113	330
CERAFONT	51	318	-104	10
CERASEMI	49	49	137	-28
CHAMANGU	-44	3	-108	-15
CHAMLAWS	-26	13	-113	330
CHRYOPPO	-47	-20	-15	100
CIRCLUTE	-74	14	144	42
CIRSARVE	-102	85	-132	33
CIRSPALU	-39	-8	-127	-50
CONIMACU	-110	93	-131	5
CONOMAJU	-43	-24	108	123
CORYAVEL	-71	4	180	-8
CORYCLAV	-27	-13	-102	91
CRATMONO	-63	5	110	-43
CYTISCOP	-9	21	-143	103

De-trended Correspondence Analysis
Species Scores

	Axis 1	Axis 2	Axis 3	Axis 4
DACTGLOM	-37	-8	-70	51
DESCCESP	-44	6	0	119
DESCFLEX	47	37	71	-19
DIGIPURP	-22	-15	-119	38
DRYOAFFI	-5	-17	-98	-43
DRYOCART	-20	-28	-77	-23
DRYODILA	-16	-16	-92	-46
DRYOFILI	-39	-16	-34	34
EPILHIRS	-110	93	-131	5
EPILMONT	-18	-37	11	-30
EQUISYLV	-41	-26	-57	6
ERICCINE	188	923	-3	2
ERICTETR	286	-47	15	38
ERIOVAGI	286	-47	15	38
EUPHAMYG	-37	-33	65	109
FAGUSYLV	-36	-22	-12	68
FESTGIGA	-83	53	-127	-68
FESTOVIN	44	-39	-51	74
FESTRUBR	-19	-20	-178	-85
FILIULMA	-112	61	344	-23
FRAGVESC	-45	-28	80	117
FRANALNU	-114	63	353	-32
FRAXEXCE	-105	56	251	5
GALETETR	-47	-30	0	131
GALIAPAR	-119	108	-63	-120
GALIMOLL	-114	78	124	52
GALIODOR	-85	29	153	137
GALISAXA	34	32	44	70
GERAROBE	-49	7	-72	-31
GEUMURBA	-117	86	106	-33
GLECHEDE	-90	44	65	40
GOODREPE	41	263	-112	10
GYMNDRYO	-16	3	-265	-38
HEDEHELI	-38	-25	40	1
HERASPHO	-96	49	104	104
HOLCLANA	-25	11	-104	261
HOLCMOLLI	-21	-27	-16	46
HYACNONS	-47	-28	35	142
HYPEHIRS	-114	63	353	-32
HYPEPULC	-32	-21	-68	48
ILEXAQUI	-23	-30	-36	-45
JUNCCONG	-30	-29	-52	110
JUNCEFFU	45	-21	13	131
JUNCSQUA	403	-37	-1	-37

De-trended Correspondence Analysis
Species Scores

	Axis 1	Axis 2	Axis 3	Axis 4
LAMIALBU	-62	-22	99	242
LAMIGALE	-72	-2	131	204
LAPSCOMM	-44	28	-139	-70
LARIKAEM	-10	-34	-11	-109
LATHLINI	-31	-39	79	132
LISTOVAT	-114	63	353	-32
LONIPERI	-22	-38	86	-47
LOTUCORN	-28	-25	-149	-72
LOTUULIG	-35	-24	-68	0
LUZUPILO	42	3	-62	11
LUZUSYLV	24	5	-21	1
LYSINEMO	-33	-27	-42	105
MALUSYLV	-41	-23	-59	47
MELAPRAT	7	-52	109	192
MELIUNIF	-39	-15	-15	134
MERCPERI	-105	62	149	35
MILIEFFU	-41	-23	-59	47
MOLICAER	86	-91	136	240
MONTPERF	-27	-5	-187	20
MYOSARVE	-110	93	-131	5
ORCHMASC	-114	63	353	-32
OXALACET	-11	2	-144	-2
PHALARUN	-110	93	-131	5
PICEABIE	-23	-18	-168	-77
PICESITC	52	8	-20	-10
PINUCONT	420	-36	-3	-47
PINUSYLV	394	-72	-51	9
PLANLANC	-28	-25	-149	-72
POLYACUL	-114	63	353	-32
POLYINTE	-28	-25	-149	-72
POTEEREC	123	-73	94	262
PRIMVERI	-114	78	124	52
PRIMVULG	-60	-7	106	38
PRUNAVIU	-31	-39	79	132
PRUNVULG	-30	-29	-52	110
PSEUMENZ	-7	6	-137	-7
PTERAQUI	-9	-46	53	-105
QUERPETR	-27	-20	-40	135
QUERROBU	-28	-29	-46	-48
RANUFICA	-112	61	342	-29
RANUREPE	-36	2	-121	89
ROSAARVE	-52	-7	35	77
RUBUCAES	-33	-25	-114	-42
RUBUFRUT	-38	-20	-16	7

De-trended Correspondence Analysis
Species Scores

	Axis 1	Axis 2	Axis 3	Axis 4
RUBUIDAE	-36	-7	-130	-54
RUBUSAXA	7	-29	38	34
RUMEACET	-21	8	-62	135
RUMEOBTU	-76	26	84	-29
RUMESANG	-107	87	-117	11
SAMBNIGR	-86	54	-113	3
SCRONODO	-97	53	89	64
SENESYLV	30	46	72	72
SILEDIOI	-63	16	-62	-17
SOLADULC	-41	-26	-57	6
SOLIVIRG	-4	-46	159	87
SORBAUCU	38	-11	-3	-75
SORBTORM	-54	-22	158	-61
STACSYLV	-104	72	-4	-15
STELGRAM	-28	-33	-29	-47
STELHOLO	-37	-34	-13	130
STELMEDI	-15	13	-38	16
STELNEMO	-16	3	-265	-38
SUCCPRAT	-31	-39	79	132
TARAOFFI	-24	-29	-39	11
TEUCSCOR	-31	-16	-48	90
THUJPLIC	174	1005	-4	6
TRICCESP	420	-36	-3	-47
TRIEEURO	56	-12	-31	8
TRISFLAV	-16	3	-265	-38
TSUGHETE	47	296	-107	10
ULEXEURO	174	1005	-4	6
ULMUGLAB	-46	-28	-26	32
URTIDIOI	-122	111	-88	-94
VACCMYRT	106	-178	43	-50
VACCULIG	125	-108	160	463
VACCVITI	405	-72	-56	12
VALEOFFI	-114	63	353	-32
VEROCHAM	-57	17	129	55
VIBUOPUL	-35	-24	-68	0
VICIORUB	7	-29	39	34
VIOLPALU	42	-3	16	141
VIOLRIVI	-20	11	-26	49